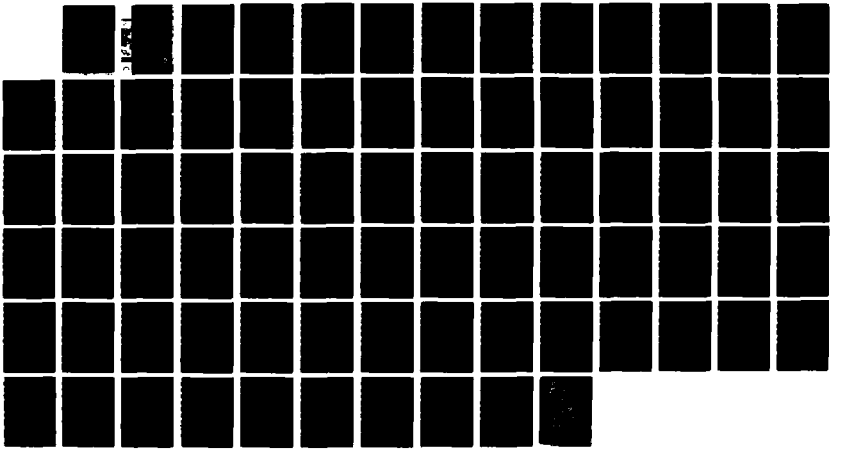
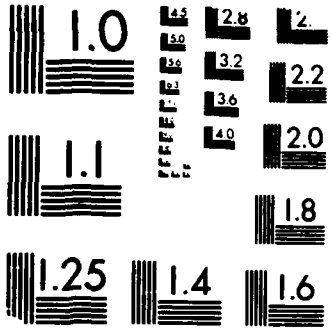
AD-A190 504 STUDIES OF THE GEOCHEMICAL STABILITY OF A SALT-SATURATED EXPANSIVE GROUT(U) ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MS STRUC L D WAKELEY ET AL SEP 87 WES/MP/SL-87-10 F/G 8/7 1/1 NL

UNCLASSIFIED





MISCELLANEOUS PAPER SL-87-10

STUDIES OF THE GEOCHEMICAL STABILITY OF A SALT-SATURATED EXPANSIVE GROUT

by

Lillian D. Wakeley, Toy S. Poole

Structures Laboratory

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
PO Box 631, Vicksburg, Mississippi 39180-0631

September 1987
Final Report

Prepared for Sandia National Laboratories
Albuquerque, New Mexico 87185

US Army Corps of Engineers

STRUCTURES LABORATORY

Destroy this report when no longer needed. Do not return it to the originator.

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

The contents of this report are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or approval of the use of such commercial products.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188
Exp. Date: Jun 30, 1986

AD-A190 504

1a REPORT SECURITY CLASSIFICATION Unclassified	1b RESTRICTIVE MARKINGS
2a SECURITY CLASSIFICATION AUTHORITY	3 DISTRIBUTION / AVAILABILITY OF REPORT Approved for public release; distribution unlimited.
2b DECLASSIFICATION / DOWNGRADING SCHEDULE	
4 PERFORMING ORGANIZATION REPORT NUMBER(S) Miscellaneous Paper SL-87-10	5 MONITORING ORGANIZATION REPORT NUMBER(S)
6a NAME OF PERFORMING ORGANIZATION USAEWES Structures Laboratory 6b OFFICE SYMBOL (If applicable) CEWES-SC	7a NAME OF MONITORING ORGANIZATION
6c ADDRESS (City, State, and ZIP Code) P.O. Box 631 Vicksburg, MS 39180-0631	7b ADDRESS (City, State, and ZIP Code)
8a NAME OF FUNDING / SPONSORING ORGANIZATION Sandia National Laboratories 8b OFFICE SYMBOL (If applicable)	9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c ADDRESS (City, State, and ZIP Code) P.O. Box 5800 Albuquerque, NM 87185	10 SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO / PROJECT NO / TASK NO / WORK UNIT ACCESSION NO

11 TITLE (Include Security Classification)

Studies of the Geochemical Stability of a Salt-saturated Expansive Grout

12 PERSONAL AUTHOR(S)
Wakeley, Lillian D. and Poole, Toy S.

13a TYPE OF REPORT	13b TIME COVERED	14 DATE OF REPORT (Year, Month, Day)	15 PAGE COUNT
Final report	FROM Oct 1986 TO Jun 198	September 1987	76

16 SUPPLEMENTARY NOTATION
Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

17 COSATI CODES			18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Atomic absorption, Ettringite, Chloroaluminate, Expansive cement, (EDX), Expansive grout,

19 ABSTRACT (Continue on reverse if necessary and identify by block number)

This report describes laboratory experiments on several aspects of durability of grout in the special environment of a repository for radioactive wastes in bedded halite rock. The variables tested include solubility of grout components, phase changes, and mobility of chloride relative to interfaces with rock and brine or freshwater.

The grout tested had large percentages of both chloride and sulfate. Chloride was more mobile when the grout was exposed to freshwater, and sulfate when exposed to brine. Removal of chloride from the grout accompanied loss of chloroaluminate phase, rather than simply dissolution of NaCl. However, chloride gradients were not apparently related to an interface between grout and halite rock.

With extended exposure to brine or freshwater, calcium represented the largest fraction of mass loss, as determined by analyses of exposure solutions. Sulfate loss was the second largest. This effect increased with time and temperature of exposure. Volume
(Continued)

20 DISTRIBUTION / AVAILABILITY OF ABSTRACT	21 ABSTRACT SECURITY CLASSIFICATION
☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	Unclassified
22a NAME OF RESPONSIBLE INDIVIDUAL Lillian D. Wakeley	22b TELEPHONE (Include Area Code) (601) 634-3215
	22c OFFICE SYMBOL CEWES-SC

DD FORM 1473, 84 MAR

83 APR edition may be used until exhausted
All other editions are obsolete

SECURITY CLASSIFICATION OF THIS PAGE
Unclassified

19. ABSTRACT (Continued).

increase of test specimens indicated continued or renewed expansion, even after the initial curing or storage period (28 days or 9 months), when the grout was exposed to water or brine. The combination of volume increase with mass loss suggests a density decrease, but this did not cause loss of physical integrity of specimens. Analyses of phase compositions and changes will be reported in a subsequent document.

PREFACE

The work described in this report is part of an ongoing research effort accomplished in the Concrete Technology Division (CTD), Structures Laboratory (SL), US Army Engineer Waterways Experiment Station (WES), under contract to Sandia National Laboratories (SNL), Albuquerque, New Mexico. Dr. E. J. Nowak was Technical Monitor for SNL for the laboratory studies reported herein, which occurred between October 1986 and June 1987, as specified in SNL Document No. 01-5244.

The work was under the general supervision of Messrs. Kenneth L. Saucier, Chief, Concrete and Evaluation Group, CTD; Richard L. Stowe, Chief, Materials and Concrete Analysis Group, CTD; John M. Scanlon, Chief, CTD; James T. Ballard, Assistant Chief, SL; and Bryant Mather, Chief, SL. Mr. Saucier was Acting Chief, CTD, during completion of the work and preparation of this report. Drs. Toy S. Poole and Lillian D. Wakeley directed the research, with assistance from Messrs. Alan Buck, J. Pete Burkes, Rudolph Richter, John Cook, Melvin Sykes, and Willie McDonald. Dr. Wakeley was Principal Investigator. She and Dr. Poole prepared this report.

COL Dwayne G. Lee, CE, is Commander and Director of WES. Dr. Robert W. Whalin is Technical Director.

CONTENTS

LIST OF TABLES

LIST OF TABLES (Concluded)

LIST OF FIGURES

CONVERSION FACTORS, NON-SI TO SI (METRIC)
UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
Fahrenheit degrees	5/9	Celsius degrees or Kelvins*
inches	25.4	millimetres
pounds (force) per square inch	0.006894757	megapascals
pounds (mass)	0.4535924	kilograms

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: $C = (5/9)(F - 32)$. To obtain Kelvin (K) readings, use $K = (5/9)(F - 32) + 273.15$.

STUDIES OF THE GEOCHEMICAL STABILITY OF A SALT-SATURATED EXPANSIVE GROUT

PART I: INTRODUCTION

1. Cement-based grouts and concretes remain an important component of a multiple-barrier seal system for planned repositories for radioactive wastes. For this use, the long-term chemical stability of the hydrated cement products is critical. The grout or concrete would not effectively seal the repository from an incursion of water if it altered to a phase composition that was unstable, either chemically or physically.

2. The properties required of grouts and concretes developed for and used at the Waste Isolation Pilot Plant (WIPP) have evolved through time, as successive formulations have benefited from further research. Salt-based mixtures first met the requirement of avoiding dissolution of water-soluble host rock during placement. They were then refined to achieve minimum permeability, longer working time, and increased expansion. Development of the expansive salt-saturated concrete (ESC), being the most recent of these research efforts, benefited most from previous research, and from increased understanding of site-specific conditions and workability requirements.

3. To meet all its performance requirements, ESC includes large quantities of both sodium chloride (NaCl) and calcium sulfate ($CaSO_4$) phases in its starting materials. In conjunction with portland cement, these components produce a chemical composition more complex than that of ordinary concretes, and a phase assemblage which would not be durable in most environments (Wakeley 1987a). The question is: is it durable in the unique environment of the WIPP, for which it was designed?

4. The hydrated sulfoaluminate phase -- ettringite -- forms by reactions among Ca and Al from the portland cement and fly ash, and sulfate from the calcium sulfate, and in so doing causes a concrete or grout to be expansive. Actually, it is not this simple when Cl also is abundant and available. In this situation, calcium chloroaluminate phases also form (they are also expansive), and the ettringite is subjected to partial or possibly total replacement by a chloroaluminate phase (tetracalcium aluminate dichloride 10-hydrate), as chloride replaces sulfate.

5. Scores of papers in the open literature discuss impacts of chlorides on concrete performance. In normal surface environments, chlorides are commonly introduced to the system after the concrete has set, and are from such sources as seawater or deicing salts. In such environments, ettringite is known to change to the chloroaluminate phase, but it is usually a temporary change, and ettringite tends to be the stable phase over the long term whenever additional sulfate is available, and with unlimited water.

6. The situation in salt-saturated expansive grout or concrete is so different that these widely published studies do not apply. Here, the concrete has virtually unlimited chloride and sulfate from the very beginning, since these are essential for the required properties. The usual concerns of routine concrete practice -- that chloride will cause corrosion of embedded reinforcing steel, or that it will facilitate deterioration by freezing and thawing -- do not apply in the WIPP environment (Wakeley 1987a). In the absence of the surface environmental hazards that cause concrete full of sulfates and chlorides to deteriorate, the question becomes one of chemical rather than physical durability. That is, is there something intrinsically unstable about a concrete full of chloride, that will prevent it from having long-term durability, underground in rock salt?

7. Because "durability" itself is not a quantifiable property of concrete, this question must be approached by tests or observations of properties each of which gives only part of the answer. This report describes laboratory experiments on several aspects of durability, including solubility of grout components, phase changes, and mobility of chloride relative to several variables.

PART II: MATERIALS AND OBJECTIVES

Materials

8. The grout with which the studies reported here are concerned was derived from the expansive salt-saturated concrete developed and described by Wakeley and Walley (1986). The change from concrete to grout required only omission of fine and coarse aggregates, with no other modifications (no changes in ratio of water to cementitious solids, for example). For these studies, grout was used instead of concrete to simplify interpretation of data from X-ray diffraction (XRD) and other analytical procedures. The grout formulation is given in Table 1. Additional information on the components and properties of this grout and its parent concrete is given by Wakeley (1987a, b, c).

Objectives

9. These experiments can be thought of as belonging to two tasks, designated Tasks 2 and 3 to be consistent with the original statement of work on this project. Experiments under Task 2 were designed to explore the movement of chloride relative to brine; and relative to an interface between halite rock and grout, as had been suggested by previous work (Wakeley and Burkes 1985), with these objectives:

a. Determine if there is a difference in chloride content of grout specimens that can be related to distance from the exterior of the specimen after exposure to freshwater or brine, as an indicator of chloride movement and localized concentration.

b. Identify a difference in chloride concentration, if any, that can be related to distance from an interface of grout with halite rock.

10. Task 3 explored dissolution of grout exposed to aqueous brine solutions, as indicated by changes in phase composition of grouts, changes in size and mass of grout specimens, and changes in concentrations of metal ions in exposure solutions. Additional objectives were to compare the effect of four variables on the observed dissolution. These variables were:

a. age of specimen prior to exposure to brine (28 days or 9 months);

b. temperature of brine solutions (27° or 38°C)*;

c. time exposed to brine (7, 45, or 90 days); and

d. concentration of NaCl in exposure solution (none, half-saturated, or saturated with NaCl).

Table 1

Components of Grout Derived from Expansive Salt-saturated Concrete

Material, CTD File No.	Mass (g) per 100 g of grout
Class H cement, RC 931	28.37
Chem Comp III, RC 929	18.92
Cal Seal, RC 932	5.67
Fly Ash, AD 844	15.97
Salt, AD 876	7.78
De-Air, AD 878	0.67
Citrate, AD 877	0.34
Water	22.28

* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 4.

PART III: PREPARATION OF SPECIMENS, AND EXPERIMENTAL DESIGN

Preparation of Grout Specimens

11. The grout specified in Table 1 was prepared by the method described in ASTM C 305-82[a]. Specimens for 28-day curing for both Tasks were cast from a single batch, with duplicate batches and specimens prepared on each of two successive days. For both Tasks, specimens subjected to further experimentation after 9-month curing had been cast in April 1986, and maintained at 81°F (27°C) in sealed containers until they were incorporated into this study. These were cylinders of grout 20 mm in diameter and 45 to 55 mm long.

12. Specimens for Task 3 experiments that began after 28 days of curing were cast within 5 min of completion of mixing, in 28-mL plastic vials. This produced cylinders 20 mm in diameter and approximately 40 mm long. Test specimens were made by sawing wafers 2 mm thick from these cylinders. Seventy-two specimens were prepared and randomly assigned to experimental conditions. Specimens were weighed (to the nearest 0.1 mg), and thickness measured in the center by micrometer (to the nearest 0.001 mm), before immersion in exposure solutions.

13. Exposure solutions were prepared using deionized water and crushed rock salt from the WIPP repository horizon. Saturated solutions were prepared by stirring an excess of rock salt in deionized water overnight at the temperature at which exposures would occur (27°C, 38°C). A surface film of undetermined composition formed, and was decanted off. Half-saturated solutions were prepared for each temperature condition by diluting an aliquot of saturated solution at that temperature 1:1 with deionized water at that temperature. The water used as an exposure solution contained only dissolved material normally found in deionized water (< 1 mg/L).

14. Specimens for Task 2 were cast as small prisms in contact with halite rock cut from cores taken from the WIPP repository horizon. Rectangular prisms of rock salt cores were cut to cross-sectional areas of 400 mm^2 or less using an oil-cooled saw. Residual oil was evaporated off at 27 to 30°C, after which the rock prisms were cleaned with ethanol.

---

a) American Society for Testing and Materials, Philadelphia, Pennsylvania, USA.

15. A collar of plastic sheeting was attached to each prepared rock prism for casting the grout in contact with rock. Grout was prepared as described previously, and the resulting specimens each had an interface between rock and grout approximately at their mid-lines. Specimens were cured and stored in heat-sealed plastic bags at 27°C until testing.

Experimental Design

Experiments under Task 2

16. There were two parts to this task. For one part, 9-month-old cylinders of grout were placed in each of two solutions -- deionized water and a saturated NaCl solution -- and stored for approximately 6 weeks at 27°C. After this storage, disk samples were cut approximately 2 mm thick, one from within 2 mm of the end of a cylinder (the outermost layer was discarded), and the other from its center. These were the only experiments for which the entire cylinder was exposed to the solutions, and the disks cut after exposure to determine gradients relative to contact with the solutions.

17. The disks were prepared for energy-dispersive X-ray analysis (EDX) by two episodes of vacuum desiccation, between which the surface was ground to remove salts deposited by the evaporated water (Wakeley and Burkes 1986). EDX spectra were collected at 16 locations along the diameter of each disk. These data were subjected to a no-standards analysis (Princeton Gamma Tech), with values for 11 elements normalized to 100%. Data from representative spectra and analyses are in Appendix A. A "C" suffix indicates data from center disks; "E" suffix signifies a sample from the end of the cylinder. Data for Cl were compared statistically, as an indicator of chloride movement and phase stability.

18. For the second part of Task 2, disk samples were cut from the specimens having an interface between halite rock from the WIPP horizon and grout, as follows: one specimen from each of two duplicate batches; two disks from each specimen, one taken from within 2 mm of the interface, and the other from within 2 mm of the end of the specimen (outermost layer discarded); disks cut at two ages, 28 and 80 days after casting.

19. The disks from interface specimens were prepared for EDX, and data were collected and analyzed as described for other samples in Task 2. Representative spectra are in Appendix B.

Experiments under Task 3

20. Grout specimens were immersed in 50 mL of exposure solution in 42-by-80-mm screw-cap plastic containers. Specimens rested on several Teflon balls of 6 mm diameter, to prevent close adherence of the specimens to the bottom of the container, thus allowing the solution essentially free access to the specimens from both sides. Containers were stored at test temperatures without agitation until they were removed at prescribed test ages for analysis. At that time, specimens were blotted dry, weighed, and measured, following the same procedures as before immersion. Mass and thickness data were expressed as percent change relative to the unexposed condition. All specimens were analyzed by X-ray diffraction (XRD), data from which will be presented in a subsequent report.

21. Following 7 and 45 days of exposure of grout specimens, test solutions were filtered through Whatman #40 filter paper and washed 5 times with deionized water at room temperature. The filtrate was acidified with HCl (methyl red), and diluted to 100 mL. During the experiments, it had become apparent that salts were crystallizing on the inside of the plastic containers. These salts were not readily soluble in water, and therefore were not being washed through the filter paper by deionized water. XRD analysis of this encrustation indicated that it was mostly halite and calcite. This resulted in a bias in the chemical analysis of the exposure solutions, in that some compounds leached from the specimens remained adhering to the walls of the container, and were under-represented in the solutions being analyzed. Therefore, an acid-wash (25% HCl) step was added in the preparation of the 90-day exposure solutions, to dissolve this encrustation from the inside of the plastic containers and include it in solution analyses.

22. Sulfate content was determined on a 50-mL aliquot of the filtered and diluted exposure solution according to ASTM C 114-85, para 15.1. A blank was run on a sample of each brine preparation (measurable amounts of SO_4 were present in the rock salt) and subtracted from the quantity of SO_4 measured in the experimental solutions.

23. Filtered and diluted exposure solutions (paragraph 13) were again diluted 1:1 with $LaCl_3$ solution (100 g/L) for analysis of Ca, Si, and Al concentrations by atomic absorption (AA) spectroscopy. Commercial solutions of Ca, Si, and Al (1,000 ppm, Baker) were used to prepare lower concentration AA standards. Concentrations of NaCl in standard solutions were matched to

experimental solutions using appropriate quantities of the same brine used for experimental exposures. $LaCl_3$ concentrations in standards were also matched with experimental solutions. Results are expressed as ppm per gram of grout in the exposed specimen.

Data analysis

24. Mean levels of measured changes in properties of the grout specimens and exposure solutions were compared with the null hypothesis that no change had occurred (aside from that due to experimental error) by Student's t-Test. Variation in levels of these properties were analyzed by analysis of variance (ANOVA) using a completely randomized factorial design (Steel and Torrie 1960). The Statistical Analysis System (SAS) program was used to perform these analyses. Treatment variables (independent variables) were: exposure time (7, 45, and 90 days), concentration of brine in the exposure solution (zero, half-saturated, saturated), period of cure prior to exposure (28 days, 9 months), and temperature (27° and 38°C). Response variables (dependent variables) were: percent change in thickness and percent change in mass of exposed wafers; and silicon, aluminum, calcium, and sulfate-ion content of the brine solutions exposed to grout specimens. Silicon, aluminum, and calcium content of brine solutions were analyzed only at 90-day exposures because of the technical problems with 7- and 45-day data, described previously. A probability of type I error (Steel and Torrie 1960, p 70) of five percent was used throughout to distinguish statistically significant results from those expected by chance.

PART IV: RESULTS AND ANALYSES

Results of Task 2

Scanning electron microscopy (SEM)/
EDX of samples from freshwater and brine

25. Examination of data from EDX spectra of disks, cut from 9-month-old cylinders after six weeks in freshwater or brine, was expected to reveal gradients in chloride distribution, if such gradients were present. The data in Table 2 are listed in the order of sample points in a line across the diameter of each disk. Any differences in chloride content between circumference and center of each disk should be apparent.

26. Simple t-tests of the means of chloride contents indicate a significant difference between the samples exposed to freshwater and those exposed to brine (10C and E vs. 11C and E), and between the center and end disks of those in freshwater (10C vs. 10E). There is no significant difference in chloride contents of the center and end disks from brine exposure (11C and 11E).

27. A plot of the data from Table 2 yields a representation (Figure 1) of chloride distribution across each disk. The center-cut disk from freshwater exposure shows that chloride content remained higher toward the axis of the cylinder (especially 10C). There are no apparent trends in chloride distribution relative to distance from the circumference on the cylinder for specimens stored in brine (11C and E).

28. Specimens also were analyzed by XRD, which revealed that chloroaluminate was present in the 9-month-old grout when these experiments were initiated. Exposure to freshwater decreased chloroaluminate to the point that it was no longer detectable by XRD, whereas chloroaluminate remained a major phase in specimens exposed to brine. In contrast, ettringite decreased markedly during exposure to brine and remained a major phase through freshwater exposure. Results of extensive XRD analyses and of SEM observations will be included in a subsequent report.

SEM/EDX, samples
from interface specimens

29. The disks cut from grout portions of interface cylinders (no test solution) also were characterized by EDX analyses, with percentages of 11

Table 2

Percentages of Chloride Calculated by No-standards Analysis of Specimens Exposed to Freshwater and Brine

		Freshwater		Brine	
Section		10C Center	10E End	11E Center	11E End
Cl, %	1	2.39	1.21	7.20	8.79
	2	2.89	1.39	9.55	10.10
	3	3.56	1.70	10.05	7.76
	4	4.17	1.97	7.93	7.35
	5	4.38	2.11	7.85	9.09
	6	5.28	2.09	8.78	13.06
	7	5.46	1.71	8.30	13.62
	8	6.25	1.93	10.71	12.94
	9	5.60	1.92	10.45	12.65
	10	4.95	1.95	10.00	7.27
	11	4.27	2.20	11.79	10.45
	12	3.84	1.96	11.51	12.65
	13	3.46	1.93	11.19	12.46
	14	3.59	1.83	11.42	11.30
	15	2.93	1.58	11.81	9.91
	16	2.30	1.29	8.19	7.52
Mean		4.08	1.80	9.80	10.43
std. dev.		1.18	0.31	1.57	2.28

elements normalized to 100% (Appendix B). Chloride contents were then compared for disks from near the interfaces of specimens after 4 weeks (2N and 3N) to those from the ends of the same specimens (2F and 3F). Likewise, additional disks cut after 11 weeks of contact between grout and rock, again from near the interface (1N and 6N) and from the end (1F and 6F), were characterized in the same manner, and chloride contents compared. As on previously described specimens, spectra were collected at 16 points across the diameter

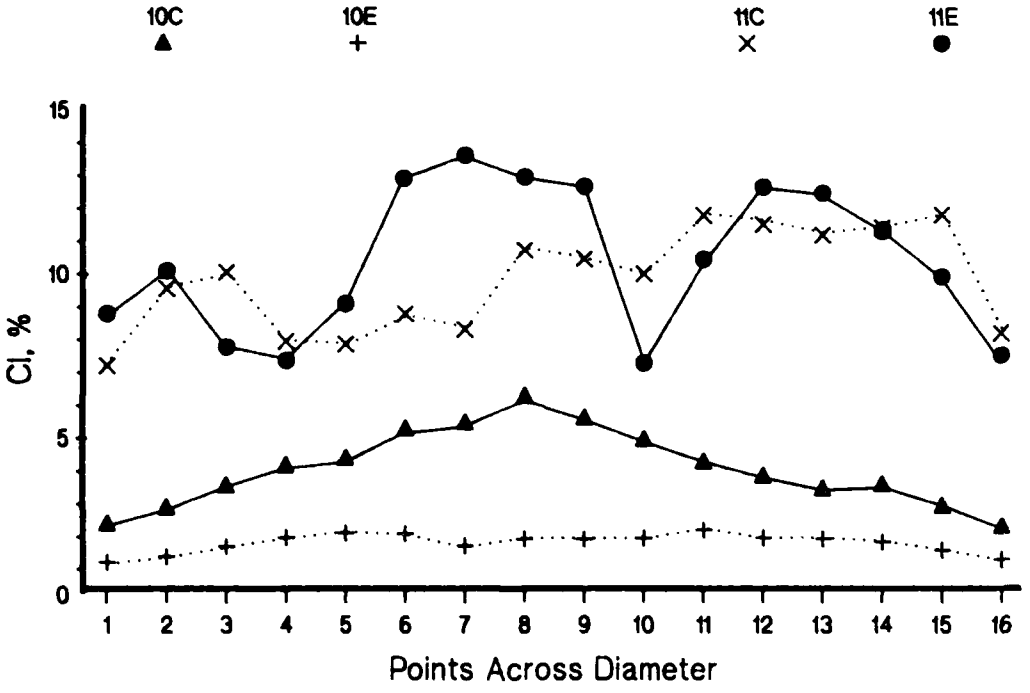


Figure 1. Percentages of chloride from points across diameters of disks cut from test specimens

of each disk. Means and standard deviations from the percentages of chloride in these spectra are in Table 3.

Table 3

Mean ($\bar{X}$) and Standard Deviation (σ) for Percentages of Chloride Determined for Interface Samples by No-standards Analysis (EDX)

		Age: 4 weeks			
Sample No.		2N[a]	2F[b]	3N[a]	3F[b]
	$\bar{X}$[c]	15.58	16.21	14.62	16.51
	σ	1.98	1.48	1.57	1.96

		Age: 11 weeks			
Sample No.		1N[a]	1F[b]	6N[a]	6F[b]
	$\bar{X}$	9.23	17.49	12.17	13.61
	σ	1.08	3.85	2.12	2.57

a) Sample cut within 2 mm of interface.
b) Sample cut within 2 mm of end.
c) No significant difference between any pair of $\bar{X}$ except 1N and 1F.

30. Specimens taken from near the interface (N suffix), instead of showing a larger percentage of chloride as was expected from previous work, in fact show a slightly smaller percentage of chloride than do disks cut from ends of specimens. This difference is only significant in one case, however. Thus the study indicates no apparent chloride gradient within this grout relative to an interface with rock salt.

Results of Task 3

31. Data are summarized in Table 4 and ANOVA's are summarized in Appendix C.

Change in thickness of disks

32. All specimens but one became thicker with exposure, with a mean

increase of 2.66% (s=2.21%, N=60). This was statistically greater than zero, as analyzed by Student's t-Test (t=9.29, 59 d.f., P<0.0001). Exposure time was the only variable found to be significant in the analysis of the variation of individual observations about this mean value (Figure 2; see also ANOVA, Appendix C). The greatest increase in thickness occurred after 45 days exposure. There was no apparent effect on change in thickness due to changes in type of solution, length of cure prior to exposure, or temperature.

Change in mass of disks

33. Specimens generally lost mass when exposed to solutions. The mean loss was 3.88% (s=2.31%, N=72). The value is significantly greater than zero, as analyzed by Student's t-Test (t=-14.25, 71 d.f., P<0.0001). Variation in mass loss was significantly related to all four independent variables (see ANOVA, Appendix C). Results are summarized in Figures 3 through 5. Specimens cured for 9 months prior to exposure to solution lost mass in approximately linear proportion to exposure time. Specimens cured for 28-days prior to exposure to solutions lost less mass than the 9-month specimens at 45 and 90 days but lost more mass at 7 days (Figure 3). As illustrated in Figure 4, mass loss tended to decrease with increasing NaCl concentration in the exposure solutions. This effect was strongest in the specimens cured for 28 days prior to exposure. As illustrated in Figure 5, mass loss increased with temperature, with specimens cured for 9 months showing the greatest temperature effect.

Chemical analysis of exposure solutions

34. The mean amount of sulfate ion leached into the exposure solutions was 124 ppm per gram of grout specimen (s=81 ppm/g, N=72), when expressed as concentration in the exposure solution. This mean is significantly greater than zero, when analyzed by Student's t-Test (t-13.10, 71 d.f., P<0.0001). Variation in the amount of sulfate ion leached was associated with time of exposure, concentration of brine, and temperature (see ANOVA, Appendix C). Sulfate contents of exposure solutions increased uniformly with time of exposure to grout specimens (Figure 6). More sulfate was leached from specimens exposed at 38°C than those exposed at 27°C. More sulfate was leached when the exposure solution contained salt, but the difference between half-saturated and saturated solutions was not statistically significant (Figure 7).

35. The mean amount of Ca ion leached from grout specimens was 688 ppm/g of grout (s=488, N=24), when expressed as concentration in the

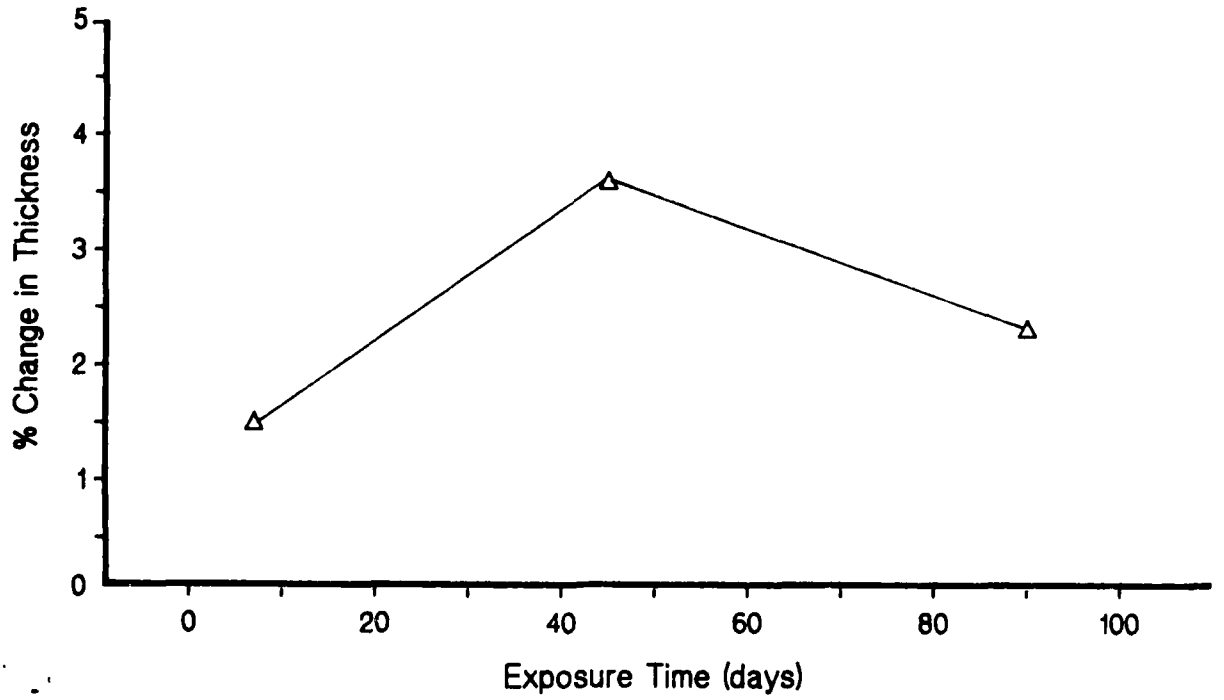


Figure 2. Change in thickness vs. exposure time

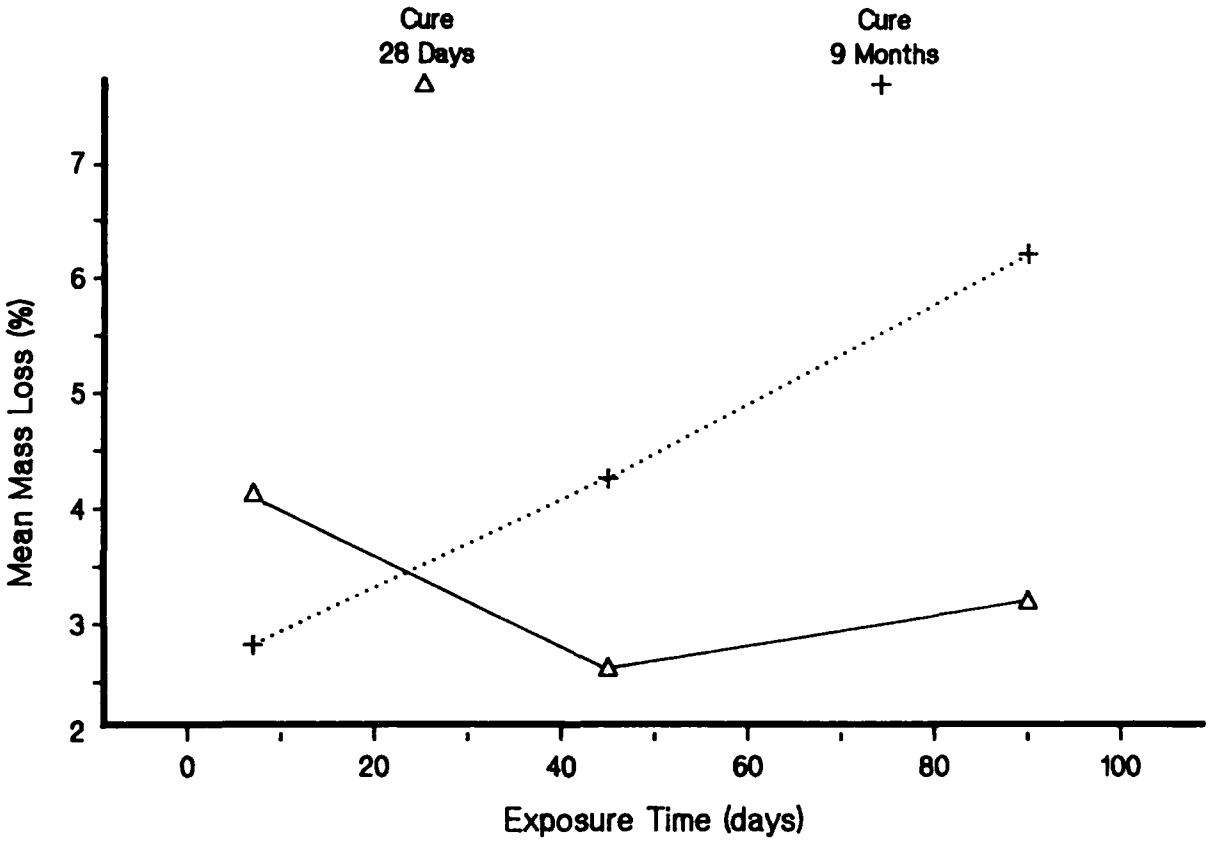


Figure 3. Mean mass loss vs. exposure time. Two levels of cure

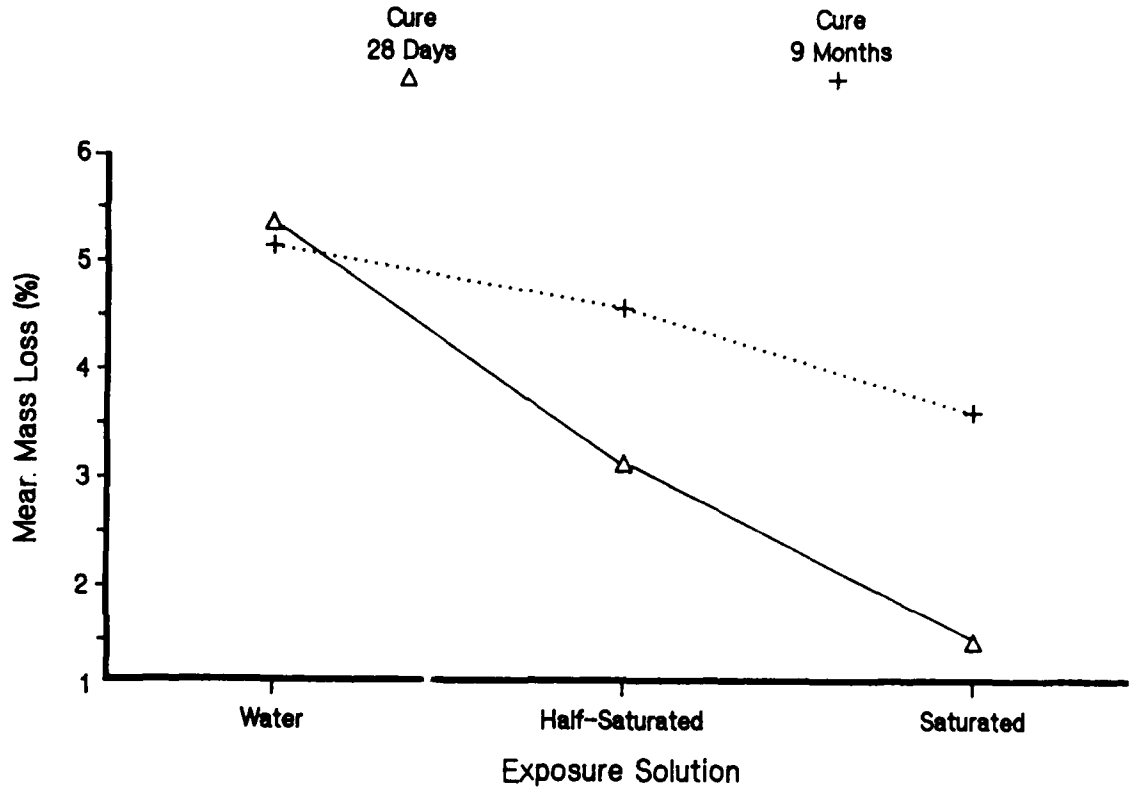


Figure 4. Mean mass loss vs. concentration of salt in exposure solutions at two levels of curing prior to exposure

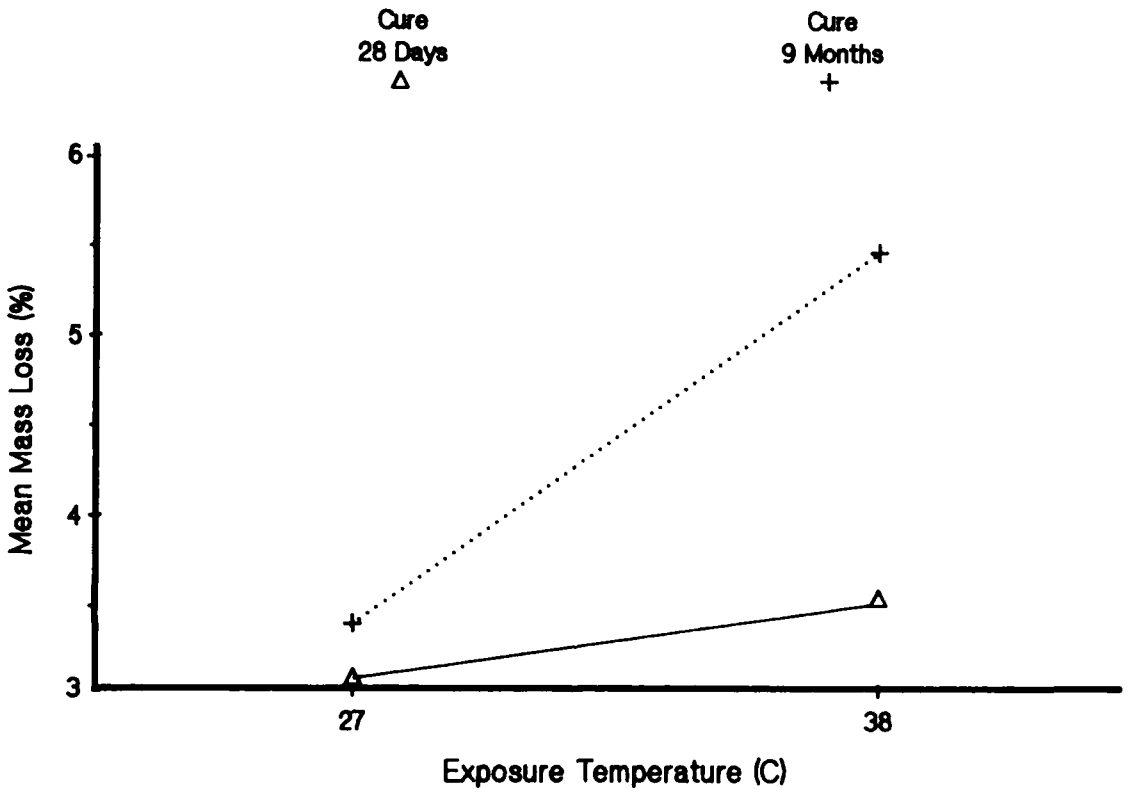


Figure 5. Mean mass loss vs. exposure temperature at two levels of curing prior to exposure

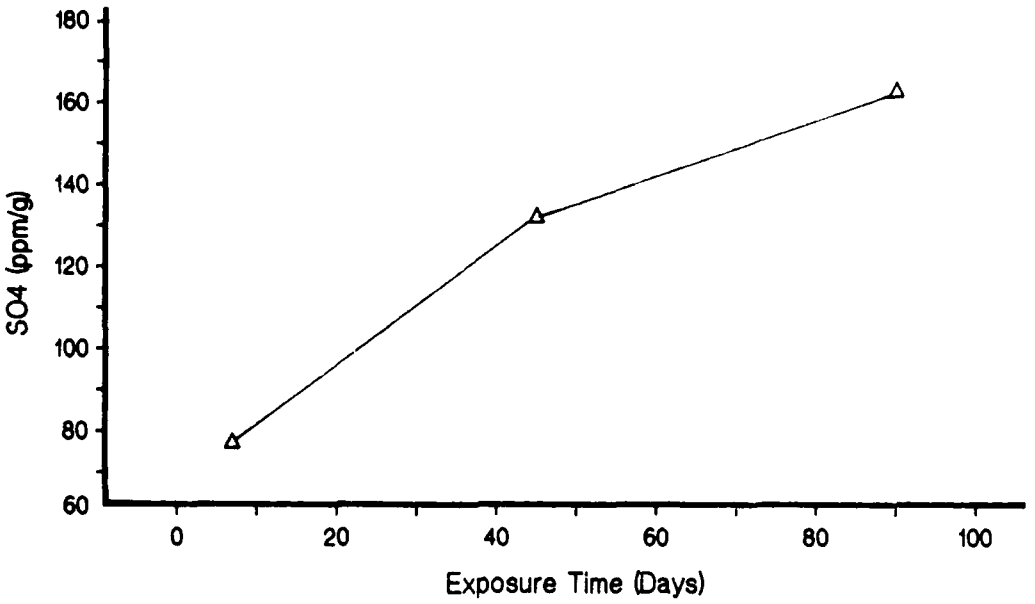


Figure 6. Sulfate concentration in exposure solutions (ppm/g of grout exposed) vs. exposure time

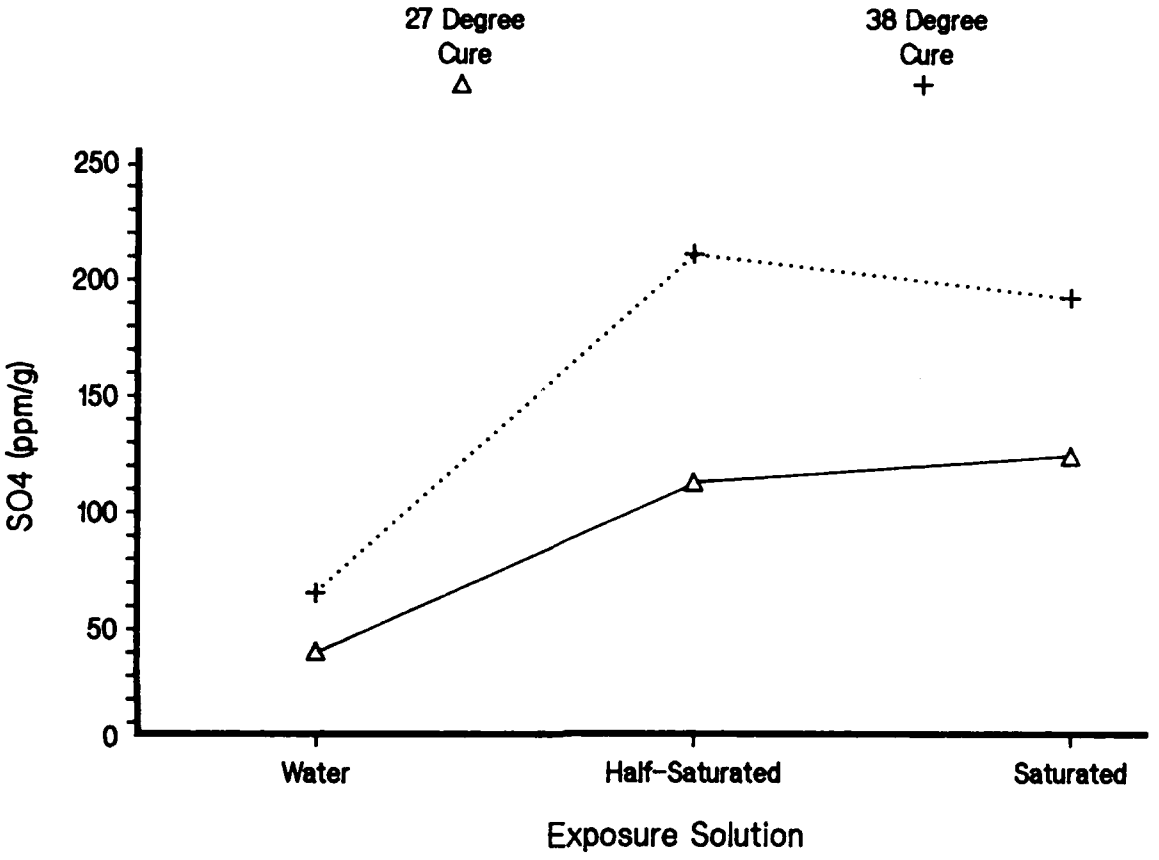


Figure 7. Sulfate concentration in exposure solutions vs. concentration of salt in exposure solutions

exposure solution. This value is significantly greater than zero when analyzed by Student's t-Test ($t=18.98$, 23 d.f., $P<0.0001$). Variation in levels of Ca leached was associated with length of cure prior to exposure to solution (see ANOVA, Appendix C). More calcium was leached from specimens that had been cured for 9 months (mean=1,114 ppm/g grout, n=12) than from specimens that had been cured for 28 days prior to exposure (mean=755 ppm/g grout, n=12).

36. The mean amount of silicon leached from grout specimens was 4.24 ppm/g of grout ($s=4.69$, $N=24$), when expressed as concentration in the exposure solution. This value is significantly greater than zero when analyzed by Student's t-Test ($t=5.21$, 23 d.f., $P<0.0001$). Variation in levels of silicon in exposure solutions was affected by the concentration of brine (see ANOVA, Appendix C). This pattern was slightly affected by the length of cure prior to exposure. This pattern is illustrated in Figure 8. Highest silicon levels were found in solutions from water exposures, followed by half-saturated brine, and saturated brine exposures, respectively.

37. The mean amount of aluminum leached from grout specimens was 7.18 ppm/g of grout ($s=5.12$, $N=24$), when expressed as concentration in the exposure solution. This value is significantly greater than zero when analyzed by Student's t-Test ($t=8.06$, 23 d.f., $P<0.0001$). Variation in levels of aluminum in exposure solutions was affected by the length of cure prior to exposure (see ANOVA, Appendix C). More aluminum was measured in solutions containing specimens that had been cured for 9 months (mean=12 ppm/g grout, n=12) than for solutions containing specimens cured for 28 days (mean=7 ppm/g grout, n=12).

Discussion and Summary

38. The chloride content of grout specimens, as determined by EDX, is significantly reduced during exposure to freshwater. This loss of chloride is not attributable simply to dissolution of unbound NaCl, but accompanies a decrease in chloroaluminate in the grout, and corresponding increase in ettringite. Cylindrical specimens exposed to freshwater show a marked decrease in chloride away from the center of the specimen. This suggests that the grout is somewhat more permeable than previous tests have indicated (Wakeley 1987a). However, its permeability to freshwater has not been tested, and removal of

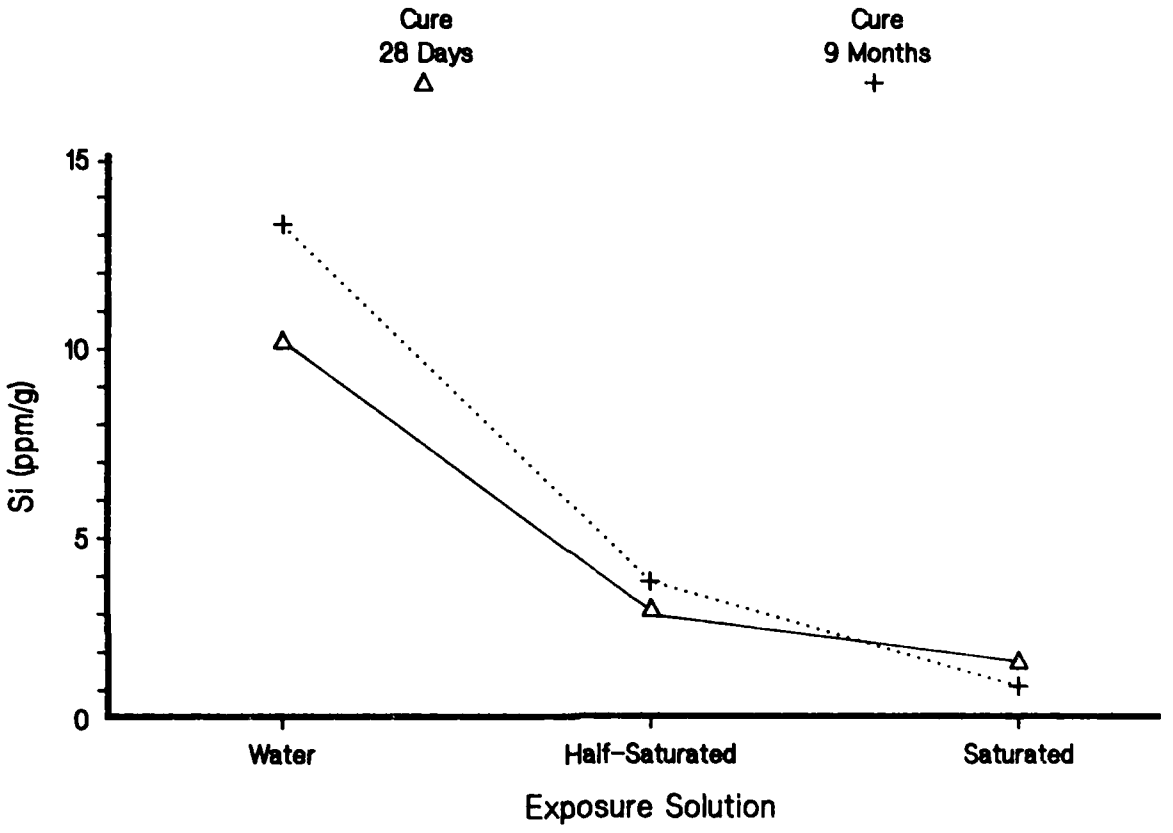


Figure 8. Silicon concentrations in exposure solutions vs. concentration of salt in exposure solutions at two levels of cure prior to exposure

chloride and accompanying phase changes could increase its permeability during testing.

39. With extended exposure to brine or freshwater, calcium represented the largest fraction of mass loss, as determined by analyses of exposure solutions. Sulfate loss was the second largest. This effect increased with time and temperature of exposure, but was decreased by the presence of salt in exposure solutions. Loss of aluminum and silicon followed, respectively, appearing in exposure solutions in concentrations that were low but statistically significant. Aluminum levels were affected by length of curing of specimens prior to exposure, and silicon levels by salt concentration.

40. Volume increase of test specimens indicated continued or renewed expansion, even after the initial curing or storage period (28 days or 9 months), when the grout was exposed to water or brine. This phenomenon generally increased with exposure time and temperature, but was less marked for specimens exposed to NaCl brine. Thus the grout was less expansive in brine than in freshwater, the freshwater favoring formation of ettringite over chloroaluminate.

41. Sulfate phases are known to be more soluble in brine than in freshwater, within a limited range of temperature (Braitsch 1971). That the sulfate is chemically active was indicated by its measured increase in solubility when the grout was exposed to brine. This was also indicated by observations via SEM/EDX, wherein EDX indicated that areas which maintained an ettringite-like structure were actually chloroaluminate, and much of the sulfate was present as what appeared to be newly crystallized gypsum.

42. The combination of volume increase with mass loss suggests a density decrease. This study establishes that sulfate is relatively easily removed from the ettringite structure, when both excess chloride and excess water are available. This caused no apparent loss of physical integrity of specimens, an observation that is consistent with previous reports (Buck 1987; Comes, Wakeley, and O'Neil 1987).

43. Variables other than age may account for the greater solubility observed for grout specimens that were 9 months old when placed in the solutions. All of the 9-month specimens were derived from a single batch of grout. Therefore, results are not supported by replication of this part of the experimental procedure (28-day results are represented by two independently prepared batches). Potential differences such as air content and resultant

density and porosity were not monitored. The possibility that the grout becomes more soluble with age should be explored further.

REFERENCES

Braitsch, O. 1971. Salt Deposits: Their Origin and Composition. Springer-Verlag, Berlin, p 34-35.

Buck, A. D. 1987. "Effect of Salt-saturated Mixing Water on Long-term Durability of Hydraulic-cement Mixtures," unpublished report for Sandia National Laboratories, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Comes, G. D., Wakeley, L. D., and O'Neil, E. F., III. 1987. "Properties of Laboratory-tested Specimens of Concrete from Small-scale Seal Performance Tests at the Waste Isolation Pilot Plant," Miscellaneous Paper SL-87-9, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Steel, R. G. D. and Torrie, J. H. 1960. Principles and Procedures of Statistics. McGraw-Hill Book Co., Inc., New York.

Wakeley, L. D. 1987a. "Durability of a Chloride-Satu ncrete for Sealing Radioactive Wastes in Bedded Rock Salt," pp 587-597 ican Concrete Institute Spec. Pub. 100

_____. 1987b. "Optimizing Workability and Expansion of a Salt-Saturated Concrete," Cement and Concrete Research Vol 17, No 5, pp 723-733.

_____. 1987c. "Relationships among Retardation, Expansion Microstructure, and Phase Composition for a Salt-Saturated Expansive Grout," pp 283-290 in Struble, Leslie and Brown, Paul, Eds., Microstructural Development During Hydration of Cement, Vol 85 of Materials Research Society Symposia Proc. Series.

Wakeley, L. D. and Burkes, J. P. 1986. "Distribution of Chloride in a Salt-saturated Grout in Contact with Halite Rock," Cement and Concrete Research, Vol 16, pp 267-274.

Wakeley, L. D. and Walley, D. M. 1986. "Development and Field Placement of an Expansive Salt-Saturated Concrete for the Waste Isolation Pilot Plant," Technical Report SL-86-36, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

APPENDIX A

DATA FROM NO-STANDARDS ANALYSES OF DISKS CUT FROM CYLINDERS AFTER EXPOSURE TO FRESHWATER AND BRINE (TASK 2)

Table A1

Sample 10C, Freshwater Exposure, Cut from Center

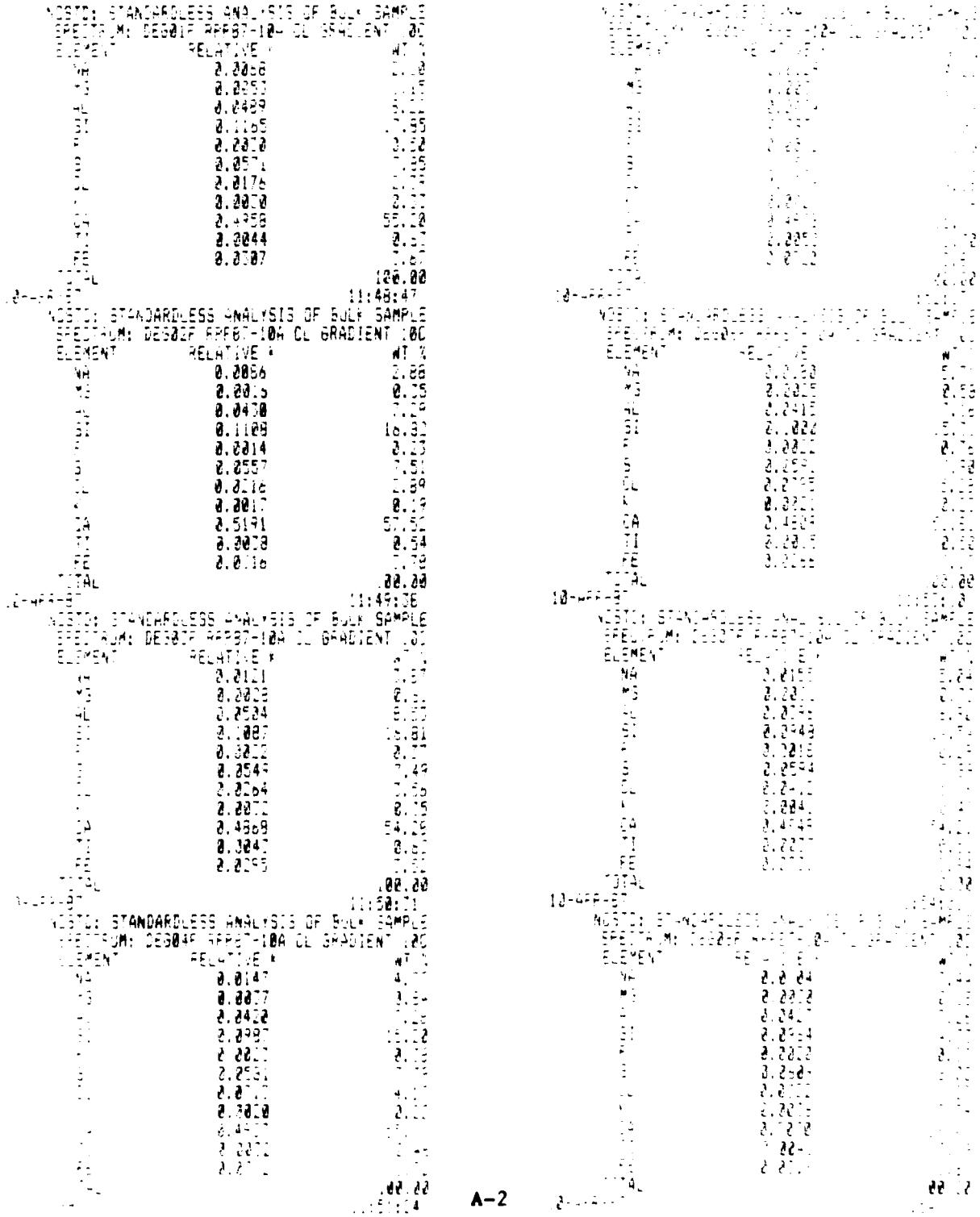


Table A1 (Concluded)

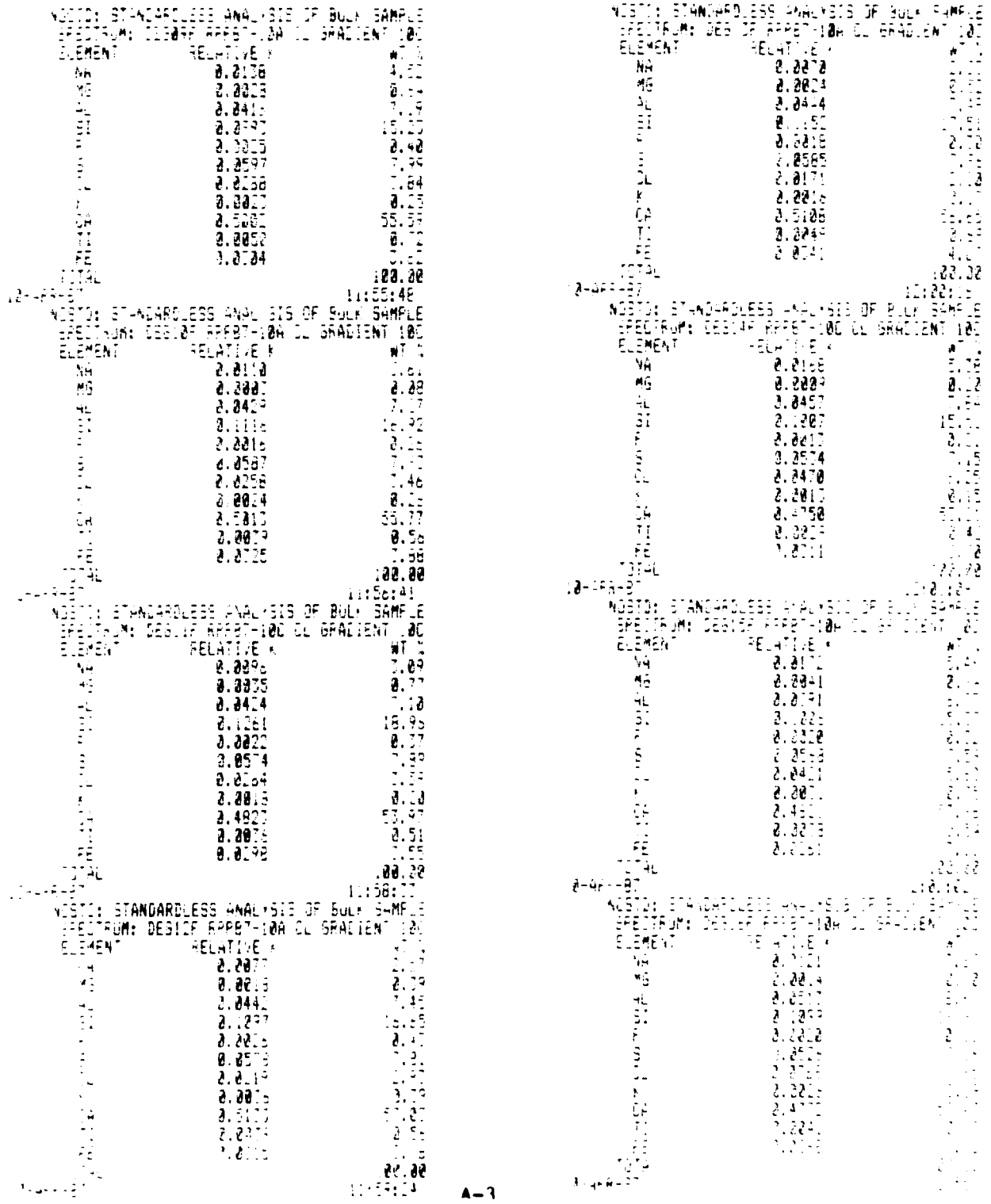
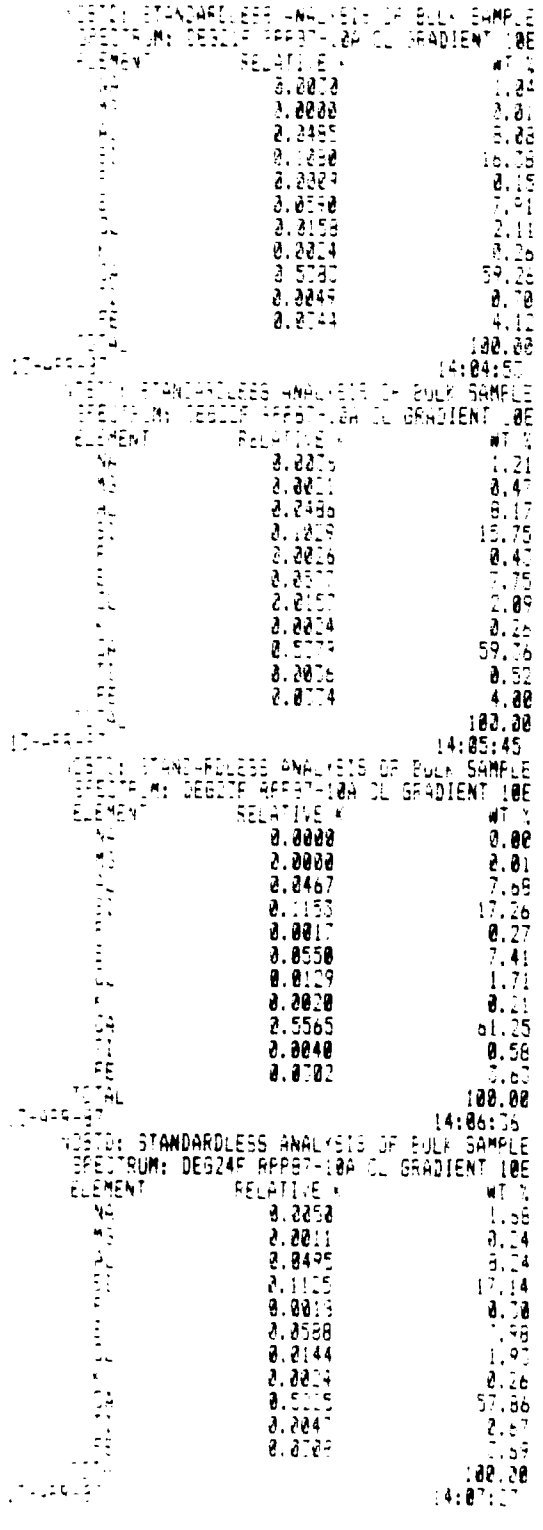


Table A2

Sample 10E, Freshwater Exposure, Cut from End



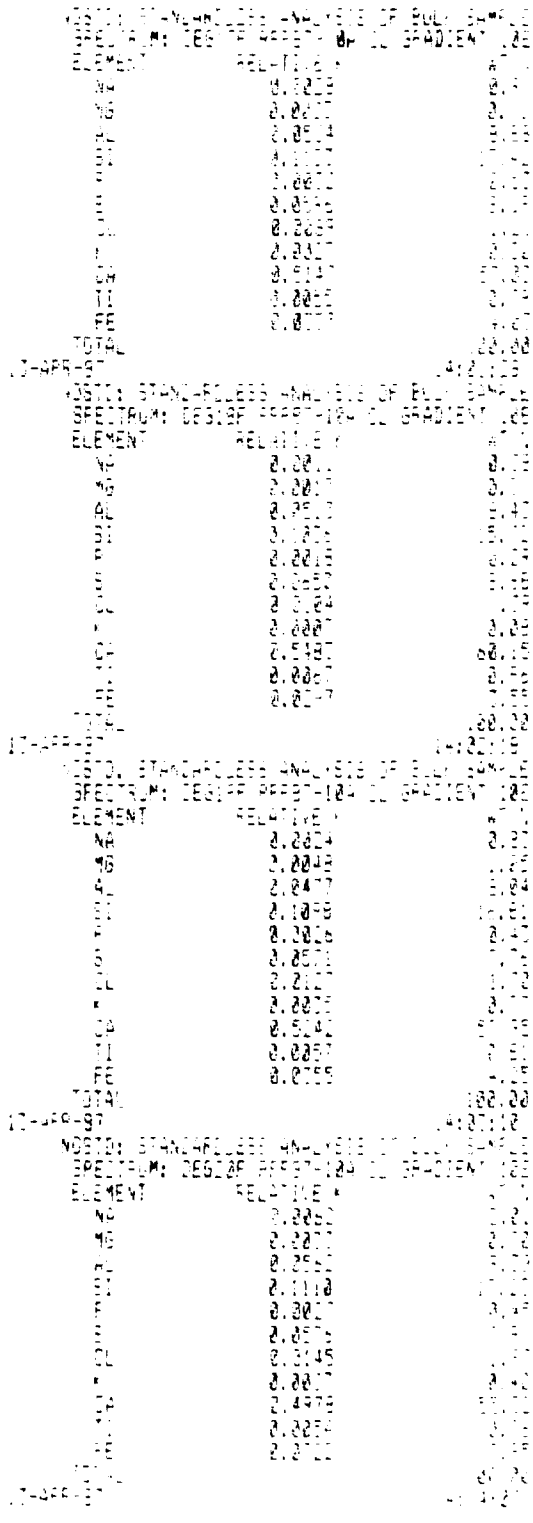


Table A2 (Concluded)

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE629F RPP87-10A CL GRADIENT 10E

ELEMENT	RELATIVE K	WT %
NA	0.0045	1.48
MG	0.0013	0.29
AL	0.0480	7.92
SI	0.1213	18.31
P	0.0019	0.33
S	0.0555	7.89
CL	0.0143	1.97
K	0.0031	0.53
CA	0.5222	57.91
TI	0.0037	0.65
FE	0.0282	3.97
TOTAL		100.00

13-APR-87 15:12:45

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE630F RPP87-10A CL GRADIENT 10E

ELEMENT	RELATIVE K	WT %
NA	0.0024	0.82
MG	0.0008	0.18
AL	0.0604	9.94
SI	0.1016	15.74
P	0.0024	0.39
S	0.0603	8.16
CL	0.0136	1.83
K	0.0032	0.55
CA	0.5287	58.52
TI	0.0039	0.55
FE	0.0295	3.53
TOTAL		100.00

13-APR-87 15:14:37

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE631F RPP87-10A CL GRADIENT 10E

ELEMENT	RELATIVE K	WT %
NA	0.0018	0.62
MG	0.0041	0.89
AL	0.0571	9.55
SI	0.1032	16.08
P	0.0027	0.44
S	0.0610	8.30
CL	0.0117	1.58
K	0.0031	0.54
CA	0.5162	57.18
TI	0.0042	0.59
FE	0.0370	4.43
TOTAL		100.00

13-APR-87 15:15:29

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE632F RPP87-10A CL GRADIENT 10E

ELEMENT	RELATIVE K	WT %
NA	0.0001	0.24
MG	0.0009	0.19
AL	0.0613	9.95
SI	0.1182	18.18
P	0.0030	0.51
S	0.0567	7.84
CL	0.0095	1.29
K	0.0027	0.50
CA	0.5139	57.00
TI	0.0049	0.72
FE	0.0224	4.00
TOTAL		100.00

13-APR-87 15:16:20

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE625F RPP87-10A CL GRADIENT 10E

ELEMENT	RELATIVE K	WT %
NA	0.0044	1.50
MG	0.0000	0.00
AL	0.0470	7.82
SI	0.1068	16.14
P	0.0024	0.39
S	0.0683	9.07
CL	0.0144	1.93
K	0.0030	0.55
CA	0.5392	59.05
TI	0.0049	0.70
FE	0.0321	3.84
TOTAL		100.00

13-APR-87 14:08:18

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE626F RPP87-10A CL GRADIENT 10E

ELEMENT	RELATIVE K	WT %
NA	0.0033	1.08
MG	0.0022	0.48
AL	0.0477	8.02
SI	0.1108	16.90
P	0.0007	0.12
S	0.0564	7.64
CL	0.0146	1.95
K	0.0028	0.51
CA	0.5290	58.42
TI	0.0049	0.72
FE	0.0356	4.26
TOTAL		100.00

13-APR-87 15:11:1...

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE627F RPP87-10A CL GRADIENT 10E

ELEMENT	RELATIVE K	WT %
NA	0.20.7	2.50
MG	0.0000	0.00
AL	0.0479	7.93
SI	0.11.6	17.0.
P	0.0027	0.44
S	0.0[illegible]	[illegible]
CL	0.0[illegible]	[illegible]
K	0.0021	0.[illegible]
CA	0.5474	59.[illegible]
TI	0.0023	0.41
FE	0.0[illegible]	4.04
TOTAL		100.00

13-APR-87 15:12:[illegible]

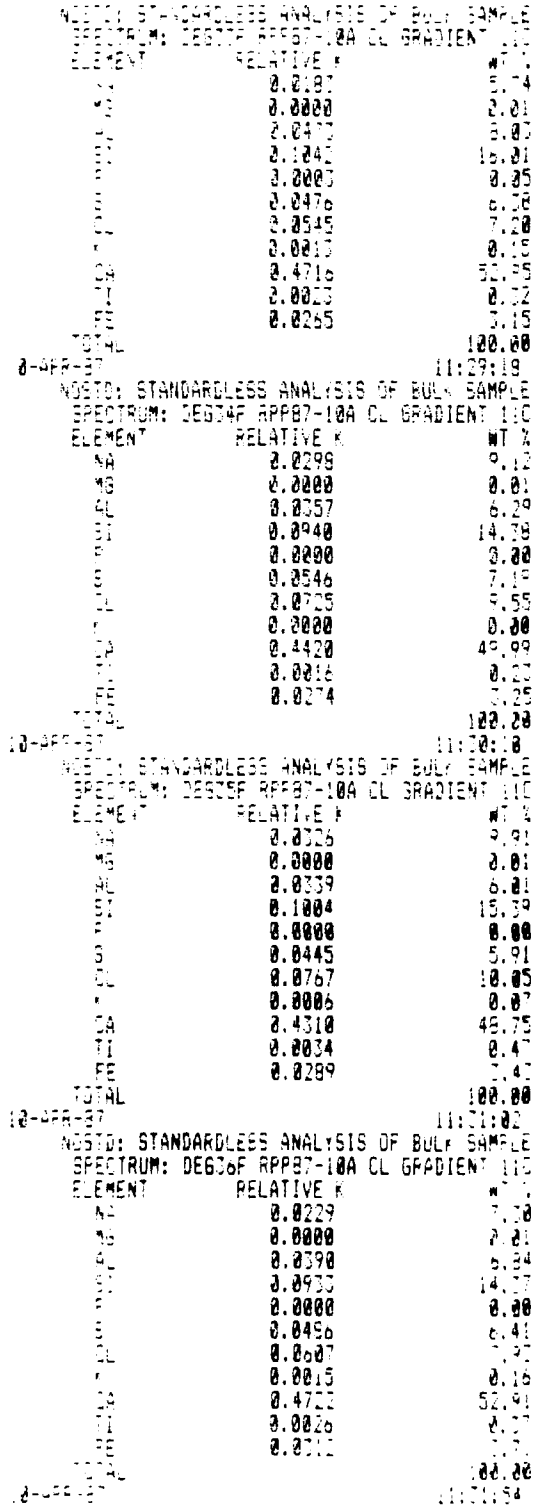
NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE628F RPP87-10A CL GRADIENT 10E

ELEMENT	RELATIVE K	WT %
NA	0.0043	[illegible]
MG	0.0000	0.00
AL	0.0[illegible]	[illegible]
SI	0.1[illegible]	[illegible]
P	0.0023	0.[illegible]
S	0.0[illegible]	[illegible]
CL	0.0[illegible]	[illegible]
K	0.0[illegible]	[illegible]
CA	0.5[illegible]	[illegible]
TI	0.0[illegible]	[illegible]
FE	0.0[illegible]	[illegible]
TOTAL		00.00

[illegible]-APR-87 [illegible]

Table A3

Sample 11C, Brine Exposure, Cut from Center



NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DEG34F RPP87-10A CL GRADIENT 11C

ELEMENT	RELATIVE K	WT %
NA	0.0299	9.12
MG	0.0000	0.01
AL	0.0357	6.29
SI	0.0940	14.78
P	0.0000	0.00
S	0.0546	7.19
CL	0.0725	9.55
K	0.0000	0.00
CA	0.4420	49.99
TI	0.0016	0.27
FE	0.0274	3.26
TOTAL		100.00

10-APR-97 11:20:18

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DEG35F RPP87-10A CL GRADIENT 11C

ELEMENT	RELATIVE K	WT %
NA	0.0326	9.91
MG	0.0000	0.01
AL	0.0339	6.01
SI	0.1004	15.39
P	0.0000	0.00
S	0.0445	5.91
CL	0.0767	10.05
K	0.0006	0.07
CA	0.4310	48.75
TI	0.0034	0.47
FE	0.0289	3.47
TOTAL		100.00

10-APR-97 11:21:02

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DEG36F RPP87-10A CL GRADIENT 11C

ELEMENT	RELATIVE K	WT %
NA	0.0229	7.10
MG	0.0000	0.01
AL	0.0390	6.84
SI	0.0933	14.27
P	0.0000	0.00
S	0.0496	6.41
CL	0.0607	8.32
K	0.0015	0.16
CA	0.4722	52.91
TI	0.0026	0.37
FE	0.0311	3.61
TOTAL		100.00

Table A3 (Concluded)

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE641F RPP87-10A CL GRADIENT 11C

ELEMENT	RELATIVE K	WT %
NA	0.0265	8.77
MG	0.0003	0.05
AL	0.0330	5.90
SI	0.0575	11.77
P	0.0002	0.00
S	0.0477	6.46
CL	0.0807	10.45
K	0.0033	0.37
CA	0.4514	51.03
TI	0.0012	0.17
FE	0.0320	3.79
TOTAL		100.00

10-APR-87 11:37:12

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE642F RPP87-10A CL GRADIENT 11C

ELEMENT	RELATIVE K	WT %
NA	0.0351	10.90
MG	0.0008	0.18
AL	0.0341	6.14
SI	0.0668	13.45
P	0.0003	0.05
S	0.0477	6.25
CL	0.0768	10.00
K	0.0033	0.38
CA	0.4359	49.29
TI	0.0025	0.35
FE	0.0254	3.00
TOTAL		100.00

10-APR-87 11:38:04

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE643F RPP87-10A CL GRADIENT 11C

ELEMENT	RELATIVE K	WT %
NA	0.0348	10.67
MG	0.0000	0.01
AL	0.0319	5.75
SI	0.0646	13.03
P	0.0000	0.00
S	0.0462	6.01
CL	0.0912	11.7[illegible]
K	0.0020	0.22
CA	0.4279	46.54
TI	0.0022	0.31
FE	0.0312	3.57
TOTAL		100.00

10-APR-87 11:38:56

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE644F RPP87-10A CL GRADIENT 11C

ELEMENT	RELATIVE K	WT %
NA	0.0253	8.07
MG	0.0000	0.01
AL	0.0320	5.51
SI	0.0695	11.51
P	0.0000	0.00
S	0.0501	6.49
CL	0.0891	11.51
K	0.0029	0.33
CA	0.4480	50.31
TI	0.0030	0.41
FE	0.0274	[illegible]
TOTAL		100.00

10-APR-87 11:39:4[illegible]

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE645F RPP87-10A CL GRADIENT 11C

ELEMENT	RELATIVE K	WT %
NA	0.0316	9.64
MG	0.0000	0.01
AL	0.0348	6.15
SI	0.0692	13.67
P	0.0000	0.00
S	0.0484	6.32
CL	0.0861	11.19
K	0.0015	0.17
CA	0.4359	49.44
TI	0.0020	0.28
FE	0.0264	[illegible]
TOTAL		100.00

10-APR-87 11:40:40

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE646F RPP87-10A CL GRADIENT 11C

ELEMENT	RELATIVE K	WT %
NA	0.0364	11.07
MG	0.0000	0.01
AL	0.0299	5.40
SI	0.0796	12.20
P	0.0000	0.00
S	0.0550	7.08
CL	0.0880	11.42
K	0.0022	0.25
CA	0.4343	49.29
TI	0.0010	0.14
FE	0.0265	3.14
TOTAL		100.00

10-APR-87 11:41:3[illegible]

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE647F RPP87-10A CL GRADIENT 11C

ELEMENT	RELATIVE K	WT %
NA	0.0332	10.07
MG	0.0000	0.01
AL	0.0354	[illegible]
SI	0.0848	17.04
P	0.0000	0.00
S	0.0469	[illegible]
CL	0.0917	11.81
K	0.0001	0.01
CA	0.4370	[illegible]
TI	0.0012	0.17
FE	0.0258	[illegible]
TOTAL		100.00

10-APR-87 11:42:[illegible]

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE648F RPP87-10A CL GRADIENT 11C

ELEMENT	RELATIVE K	WT %
NA	0.0207	[illegible]
MG	0.0000	0.01
AL	0.0294	[illegible]
SI	[illegible]	[illegible]
P	0.0003	[illegible]
S	[illegible]	[illegible]
CL	[illegible]	[illegible]
K	0.0012	[illegible]
CA	[illegible]	[illegible]
TI	[illegible]	[illegible]
FE	[illegible]	[illegible]
TOTAL		[illegible]

10-APR-87 [illegible]

Table A4

Sample 11E, Brine Exposure, Cut from End

Table A4 (Concluded)

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DEG60F RPP87-10A CL GRADIENT 11E

ELEMENT	RELATIVE K	WT %
NA	0.0392	11.85
MG	0.0000	0.01
AL	0.0304	5.53
SI	0.0768	11.86
P	0.0000	0.00
S	0.0474	6.10
CL	0.0985	12.65
K	0.0000	0.00
CA	0.4293	48.71
TI	0.0005	0.07
FE	0.0272	3.21
TOTAL		100.00

13-APR-87 13:17:44

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DEG61F

ELEMENT	RELATIVE K	WT %
NA	0.0225	7.08
MG	0.0011	0.50
AL	0.0384	6.73
SI	0.0959	14.72
P	0.0021	0.35
S	0.0500	6.65
CL	0.0553	7.27
K	0.0017	0.22
CA	0.4699	52.66
TI	0.0039	0.55
FE	0.0277	3.29
TOTAL		100.00

13-APR-87 13:19:59

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DEG62F RPP87-10A CL GRADIENT 11E

ELEMENT	RELATIVE K	WT %
NA	0.0335	10.04
MG	0.0000	0.01
AL	0.0398	7.02
SI	0.0936	14.50
P	0.0010	0.16
S	0.0483	6.41
CL	0.0793	10.45
K	0.0015	0.17
CA	0.4183	47.50
TI	0.0039	0.54
FE	0.0271	3.20
TOTAL		100.00

13-APR-87 13:20:52

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DEG63F RPP87-10A CL GRADIENT 11E

ELEMENT	RELATIVE K	WT %
NA	0.0377	11.26
MG	0.0000	0.01
AL	0.0317	5.68
SI	0.0884	13.54
P	0.0000	0.00
S	0.0445	5.80
CL	0.0978	12.65
K	0.0000	0.00
CA	0.4104	47.82
TI	0.0014	0.33
FE	0.0245	2.91
TOTAL		100.00

13-APR-87 13:21:44

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DEG64F RPP87-10A CL GRADIENT 11E

ELEMENT	RELATIVE K	WT %
NA	[illegible]	[illegible]
MG	0.0000	0.01
AL	0.0365	[illegible]
SI	[illegible]	[illegible]
P	0.0000	0.00
S	0.0474	[illegible]
CL	[illegible]	[illegible]
K	[illegible]	[illegible]
CA	[illegible]	[illegible]
TI	[illegible]	[illegible]
FE	[illegible]	[illegible]
TOTAL		100.00

13-APR-87 [illegible]

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DEG65F RPP87-10A CL GRADIENT 11E

ELEMENT	RELATIVE K	WT %
NA	[illegible]	[illegible]
MG	[illegible]	[illegible]
AL	[illegible]	6.05
SI	0.0815	[illegible]
P	0.0004	0.06
S	[illegible]	[illegible]
CL	[illegible]	[illegible]
K	[illegible]	0.14
CA	0.4314	[illegible]
TI	[illegible]	[illegible]
FE	[illegible]	3.15
TOTAL		100.00

13-APR-87 [illegible]

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: [illegible] RPP87-10A CL GRADIENT 11E

ELEMENT	RELATIVE K	WT %
NA	0.0220	5.94
MG	0.0006	[illegible]
AL	[illegible]	[illegible]
SI	[illegible]	[illegible]
P	[illegible]	[illegible]
S	[illegible]	[illegible]
CL	[illegible]	[illegible]
K	[illegible]	[illegible]
CA	0.4750	[illegible]
TI	[illegible]	[illegible]
FE	[illegible]	[illegible]
TOTAL		100.00

13-APR-87 [illegible]

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: [illegible] RPP87-10A CL GRADIENT 11E

ELEMENT	RELATIVE K	WT %
NA	[illegible]	[illegible]
MG	0.0001	[illegible]
AL	[illegible]	[illegible]
SI	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
CA	[illegible]	[illegible]
TI	[illegible]	[illegible]
FE	[illegible]	[illegible]
TOTAL		[illegible]

13-APR-87 [illegible]

APPENDIX B

DATA FROM NO STANDARDS ANALYSES OF DISKS CUT FROM INTERFACE SPECIMENS (TASK 2)

Table B1

Sample 2N, 4 Weeks, Cut Near Interface

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE657E RPP87-10A CL GRADIENT 2N

ELEMENT	RELATIVE K	WT %
NA	0.0643	17.71
AL	0.0266	5.00
SI	0.0658	10.31
S	0.0460	5.86
CL	0.1319	16.91
K	0.0112	1.34
CA	0.3463	40.24
TI	0.0008	0.11
FE	0.0215	2.52
TOTAL		100.00

21-SEP-87 13:05:28

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE658E RPP87-10A CL GRADIENT 2N

ELEMENT	RELATIVE K	WT %
NA	0.0396	11.95
AL	0.0322	5.86
SI	0.0720	11.17
S	0.0474	6.06
CL	0.1053	13.49
K	0.0137	1.57
CA	0.4038	46.33
TI	0.0007	0.09
FE	0.0294	3.47
TOTAL		100.00

21-SEP-87 13:07:11

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE659E RPP87-10A CL GRADIENT 2N

ELEMENT	RELATIVE K	WT %
NA	0.0457	13.43
AL	0.0206	5.60
SI	0.0729	11.32
S	0.0455	5.84
CL	0.1087	13.93
K	0.0139	1.61
CA	0.3912	44.99
TI	0.0015	0.21
FE	0.0259	3.06
TOTAL		100.00

21-SEP-87 13:07:51

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE660E RPP87-10A CL GRADIENT 2N

ELEMENT	RELATIVE K	WT %
NA	0.0342	10.63
AL	0.0364	6.60
SI	0.0769	12.04
S	0.0513	6.67
CL	0.0760	9.87
K	0.0077	0.86
CA	0.4344	49.13
TI	0.0019	0.26
FE	0.0333	3.94
TOTAL		100.00

21-SEP-87 13:08:32

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE661E RPP87-10A CL GRADIENT 2N

ELEMENT	RELATIVE K	WT %
NA	0.0634	17.77
AL	0.0293	5.57
SI	0.0598	9.52
S	0.0371	4.72
CL	0.1311	16.60
K	0.0064	0.75
CA	0.3671	42.24
TI	0.0005	0.07
FE	0.0235	2.76
TOTAL		100.00

21-SEP-87 13:10:51

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE662E RPP87-10A CL GRADIENT 2N

ELEMENT	RELATIVE K	WT %
NA	0.0656	18.46
AL	0.0259	4.98
SI	0.0588	9.34
S	0.0370	4.71
CL	0.1313	16.59
K	0.0079	0.92
CA	0.3638	41.87
TI	0.0005	0.07
FE	0.0261	3.06
TOTAL		100.00

21-SEP-87 13:11:32

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE663E RPP87-10A CL GRADIENT 2N

ELEMENT	RELATIVE K	WT %
NA	0.0697	19.31
AL	0.0235	4.55
SI	0.0570	9.02
S	0.0366	4.62
CL	0.1421	17.88
K	0.0070	0.83
CA	0.3557	41.09
TI	0.0000	0.00
FE	0.0231	2.71
TOTAL		100.00

21-SEP-87 13:12:13

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE664E RPP87-10A CL GRADIENT 2N

ELEMENT	RELATIVE K	WT %
NA	0.0677	18.67
AL	0.0256	4.89
SI	0.0570	8.99
S	0.0385	4.85
CL	0.1456	18.34
K	0.0052	0.61
CA	0.3563	41.21
TI	0.0000	0.00
FE	0.0207	2.43
TOTAL		100.00

21-SEP-87 13:12:53

Table B1 (Concluded)

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE605E RPP87-10A CL GRADIENT 2N

ELEMENT	RELATIVE K	WT %
NA	0.0668	19.11
MG	0.0012	0.32
AL	0.0244	4.81
SI	0.0574	9.25
S	0.0321	4.10
CL	0.1195	15.06
K	0.0042	0.49
CA	0.3798	43.26
FE	0.0307	3.59
TOTAL		100.00

21-SEP-87 13:20:54

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE606E RPP87-10A CL GRADIENT 2N

ELEMENT	RELATIVE K	WT %
NA	0.0675	19.27
MG	0.0006	0.18
AL	0.0256	5.04
SI	0.0496	8.00
S	0.0324	4.09
CL	0.1318	16.47
K	0.0061	0.71
CA	0.3739	42.77
FE	0.0296	3.47
TOTAL		100.00

21-SEP-87 13:21:32

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE607E RPP87-10A CL GRADIENT 2N

ELEMENT	RELATIVE K	WT %
NA	0.0687	19.45
MG	0.0019	0.51
AL	0.0280	5.53
SI	0.0489	7.98
S	0.0364	4.63
CL	0.1255	15.85
K	0.0051	0.60
CA	0.3657	41.83
FE	0.0311	3.64
TOTAL		100.00

21-SEP-87 13:22:11

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE608E RPP87-10A CL GRADIENT 2N

ELEMENT	RELATIVE K	WT %
NA	0.0699	19.84
MG	0.0026	0.72
AL	0.0214	4.27
SI	0.0549	8.85
S	0.0308	3.92
CL	0.1292	16.22
K	0.0044	0.52
CA	0.3672	41.97
FE	0.0316	3.70
TOTAL		100.00

21-SEP-87 13:22:50

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE601E RPP87-10A CL GRADIENT 2N

ELEMENT	RELATIVE K	WT %
NA	0.0707	20.29
MG	0.0001	0.02
AL	0.0237	4.72
SI	0.0507	8.23
S	0.0360	4.58
CL	0.1200	15.12
K	0.0042	0.49
CA	0.3739	42.58
FE	0.0340	3.98
TOTAL		100.00

21-SEP-87 13:17:26

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE602E RPP87-10A CL GRADIENT 2N

ELEMENT	RELATIVE K	WT %
NA	0.0700	19.75
MG	0.0014	0.37
AL	0.0258	5.10
SI	0.0545	8.84
S	0.0344	4.40
CL	0.1215	15.36
K	0.0064	0.74
CA	0.3663	41.88
FE	0.0304	3.56
TOTAL		100.00

21-SEP-87 13:18:07

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE603E RPP87-10A CL GRADEIENT 2N

ELEMENT	RELATIVE K	WT %
NA	0.0680	19.49
MG	0.0026	0.71
AL	0.0247	4.93
SI	0.0521	8.49
S	0.0301	3.84
CL	0.1207	15.14
K	0.0065	0.75
CA	0.3760	42.82
FE	0.0326	3.82
TOTAL		100.00

21-SEP-87 13:18:46

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE604E RPP87-10A CL GRADIENT 2N

ELEMENT	RELATIVE K	WT %
NA	0.0695	19.81
MG	0.0001	0.02
AL	0.0245	4.84
SI	0.0525	8.48
S	0.0362	4.60
CL	0.1240	15.64
K	0.0069	0.80
CA	0.3678	42.07
FE	0.0320	3.75
TOTAL		100.00

21-SEP-87 13:19:24

Table B2

Sample 2N, 4 Weeks, Cut Near Interface

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE649E RPP87-10A CL GRADIENT 2F

ELEMENT	RELATIVE K	WT %
NA	0.0644	18.33
AL	0.0280	5.40
SI	0.0591	9.49
S	0.0379	4.86
CL	0.1161	14.74
K	0.0035	0.41
CA	0.3807	43.42
TI	0.0011	0.15
FE	0.0273	3.20
TOTAL		100.00

21-SEP-87 12:41:08

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE650E RPP87-10A CL GRADIENT 2F

ELEMENT	RELATIVE K	WT %
NA	0.0714	19.62
AL	0.0258	4.99
SI	0.0575	9.17
S	0.0420	5.34
CL	0.1395	17.76
K	0.0038	0.45
CA	0.3413	39.46
TI	0.0011	0.15
FE	0.0261	3.05
TOTAL		100.00

21-SEP-87 12:43:14

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE651E RPP87-10A CL GRADIENT 2F

ELEMENT	RELATIVE K	WT %
NA	0.0741	20.07
AL	0.0277	5.35
SI	0.0531	8.50
S	0.0453	5.74
CL	0.1381	17.61
K	0.0038	0.46
CA	0.3431	39.69
TI	0.0000	0.00
FE	0.0220	2.58
TOTAL		100.00

21-SEP-87 12:45:42

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE652E RPP87-10A CL GRADIENT 2F

ELEMENT	RELATIVE K	WT %
NA	0.0785	20.91
AL	0.0284	5.50
SI	0.0605	9.74
S	0.0360	4.62
CL	0.1400	17.86
K	0.0059	0.71
CA	0.3258	37.77
TI	0.0014	0.18
FE	0.0231	2.70
TOTAL		100.00

21-SEP-87 12:46:23

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE653E RPP87-10A CL GRADIENT 2F

ELEMENT	RELATIVE K	WT %
NA	0.0727	19.76
AL	0.0277	5.34
SI	0.0612	9.78
S	0.0408	5.23
CL	0.1344	17.20
K	0.0053	0.63
CA	0.3372	39.01
TI	0.0008	0.11
FE	0.0250	2.93
TOTAL		100.00

21-SEP-87 12:47:03

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE654E RPP87-10A CL GRADIENT 2F

ELEMENT	RELATIVE K	WT %
NA	0.0650	18.31
AL	0.0285	5.49
SI	0.0612	9.80
S	0.0409	5.25
CL	0.1204	15.39
K	0.0036	0.42
CA	0.3657	41.92
TI	0.0011	0.15
FE	0.0279	3.27
TOTAL		100.00

21-SEP-87 12:47:44

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE655E RPP87-10A CL GRADIENT 2F

ELEMENT	RELATIVE K	WT %
NA	0.0845	22.45
AL	0.0255	5.04
SI	0.0524	8.50
S	0.0363	4.62
CL	0.1434	18.18
K	0.0027	0.32
CA	0.3303	38.17
TI	0.0000	0.00
FE	0.0233	2.72
TOTAL		100.00

21-SEP-87 12:49:22

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE656E RPP87-10A CL GRADIENT 2F

ELEMENT	RELATIVE K	WT %
NA	0.0860	22.79
AL	0.0222	4.39
SI	0.0561	9.04
S	0.0371	4.73
CL	0.1418	18.02
K	0.0036	0.43
CA	0.3270	37.82
TI	0.0002	0.03
FE	0.0236	2.75
TOTAL		100.06

21-SEP-87 12:50:03

Table B2 (Concluded)

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE609E RPP87-10A CL GRADIENT 2F

ELEMENT	RELATIVE K	WT %
NA	0.0696	19.71
MG	0.0001	0.02
AL	0.0288	5.66
SI	0.0558	9.09
S	0.0394	5.00
CL	0.1149	14.69
K	0.0028	0.33
CA	0.3633	41.47
FE	0.0338	3.95
TOTAL		100.00

21-SEP-87 12:56:42

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE610E RPP87-10A CL GRADIENT 2F

ELEMENT	RELATIVE K	WT %
NA	0.0622	17.25
MG	0.0009	0.23
AL	0.0282	5.32
SI	0.0883	13.94
S	0.0343	4.55
CL	0.1086	14.13
K	0.0030	0.35
CA	0.3560	40.87
FE	0.0286	3.35
TOTAL		100.00

21-SEP-87 12:57:21

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE611E RPP87-10A CL GRADIENT 2F

ELEMENT	RELATIVE K	WT %
NA	0.0566	15.60
MG	0.0001	0.02
AL	0.0264	4.84
SI	0.1069	16.47
S	0.0342	4.61
CL	0.1070	14.06
K	0.0014	0.17
CA	0.3563	41.03
FE	0.0267	3.14
TOTAL		100.00

21-SEP-87 12:57:59

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE612E RPP87-10A CL GRADIENT 2F

ELEMENT	RELATIVE K	WT %
NA	0.0652	18.61
MG	0.0016	0.44
AL	0.0293	5.74
SI	0.0549	8.93
S	0.0396	5.09
CL	0.1150	14.66
K	0.0033	0.38
CA	0.3704	42.27
FE	0.0331	3.88
TOTAL		100.00

21-SEP-87 12:58:38

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE613E RPP87-10A CL GRADIENT 2F

ELEMENT	RELATIVE K	WT %
NA	0.0715	20.04
MG	0.0017	0.47
AL	0.0264	5.22
SI	0.0586	9.54
S	0.0315	4.06
CL	0.1227	15.57
K	0.0027	0.32
CA	0.3588	41.00
FE	0.0322	3.77
TOTAL		100.00

21-SEP-87 13:00:15

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE614E RPP87-10A CL GRADIENT 2F

ELEMENT	RELATIVE K	WT %
NA	0.0685	19.63
MG	0.0001	0.02
AL	0.0229	4.53
SI	0.0535	8.60
S	0.0302	3.82
CL	0.1286	16.06
K	0.0031	0.36
CA	0.3815	43.46
FE	0.0300	3.52
TOTAL		100.00

21-SEP-87 13:00:53

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE615E RPP87-10A CL GRADIENT 2F

ELEMENT	RELATIVE K	WT %
NA	0.0682	19.37
MG	0.0006	0.16
AL	0.0248	4.86
SI	0.0526	8.45
S	0.0367	4.55
CL	0.1328	16.74
K	0.0038	0.44
CA	0.3636	41.69
FE	0.0311	3.64
TOTAL		100.00

21-SEP-87 13:01:32

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE616E RPP87-10A CL GRADIENT 2F

ELEMENT	RELATIVE K	WT %
NA	0.0656	18.71
MG	0.0008	0.21
AL	0.0256	4.99
SI	0.0639	10.26
S	0.0310	4.00
CL	0.1244	15.76
K	0.0033	0.39
CA	0.3650	41.75
FE	0.0336	3.94
TOTAL		100.00

21-SEP-87 13:02:11

Table B3

Sample 3N, 4 Weeks, Cut Near Interface

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE617E RPP87-10A CL GRADIENT 3N

ELEMENT	RELATIVE K	WT %
NA	0.0802	21.50
AL	0.0238	4.66
SI	0.0606	9.72
S	0.0406	5.21
CL	0.1280	16.39
K	0.0069	0.81
CA	0.3369	38.90
TI	0.0009	0.12
FE	0.0230	2.69
TOTAL		100.00

21-SEP-87 13:25:34

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE618E RPP87-10A CL GRADIENT 3N

ELEMENT	RELATIVE K	WT %
NA	0.0710	19.46
AL	0.0262	5.05
SI	0.0650	10.36
S	0.0401	5.16
CL	0.1238	15.86
K	0.0069	0.82
CA	0.3496	40.30
TI	0.0014	0.19
FE	0.0240	2.81
TOTAL		100.00

21-SEP-87 13:26:14

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE619E RPP87-10A CL GRADIENT 3N

ELEMENT	RELATIVE K	WT %
NA	0.0703	19.38
AL	0.0316	6.09
SI	0.0627	10.15
S	0.0393	5.10
CL	0.1130	14.52
K	0.0080	0.94
CA	0.3548	40.73
TI	0.0025	0.34
FE	0.0242	2.83
TOTAL		100.00

21-SEP-87 13:26:54

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE620E RPP87-10A CL GRADIENT 3N

ELEMENT	RELATIVE K	WT %
NA	0.0710	19.31
AL	0.0325	6.23
SI	0.0705	11.40
S	0.0423	5.57
CL	0.1017	13.25
K	0.0083	0.97
CA	0.3493	40.10
TI	0.0021	0.28
FE	0.0246	2.88
TOTAL		100.00

21-SEP-87 13:27:33

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE621E RPP87-10A CL GRADIENT 3N

ELEMENT	RELATIVE K	WT %
NA	0.0672	18.74
AL	0.0299	5.75
SI	0.0666	10.72
S	0.0381	4.95
CL	0.1094	14.06
K	0.0073	0.85
CA	0.3635	41.65
TI	0.0012	0.16
FE	0.0268	3.14
TOTAL		100.00

21-SEP-87 13:28:59

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE622E RPP87-10A CL GRADIENT 3N

ELEMENT	RELATIVE K	WT %
NA	0.0736	19.90
AL	0.0236	4.54
SI	0.0686	10.85
S	0.0386	4.97
CL	0.1284	16.44
K	0.0060	0.71
CA	0.3468	40.05
TI	0.0000	0.00
FE	0.0216	2.53
TOTAL		100.00

21-SEP-87 13:29:39

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE623E RPP87-10A CL GRADIENT 3N

ELEMENT	RELATIVE K	WT %
NA	0.0691	19.04
AL	0.0274	5.26
SI	0.0637	10.16
S	0.0371	4.77
CL	0.1290	16.44
K	0.0046	0.54
CA	0.3545	40.82
TI	0.0008	0.10
FE	0.0245	2.87
TOTAL		100.00

21-SEP-87 13:30:19

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE624E RPP87-10A CL GRADIENT 3N

ELEMENT	RELATIVE K	WT %
NA	0.0687	18.74
AL	0.0291	5.54
SI	0.0688	10.95
S	0.0394	5.10
CL	0.1244	16.00
K	0.0067	0.79
CA	0.3463	39.99
TI	0.0010	0.14
FE	0.0234	2.74
TOTAL		100.00

21-SEP-87 13:30:59

Table B3 (Concluded)

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE637E RPP87-10A CL GRADIENT 3N

ELEMENT	RELATIVE K	WT %
NA	0.0713	19.28
AL	0.0318	6.08
SI	0.0730	11.76
S	0.0392	5.15
CL	0.1057	13.73
K	0.0065	0.76
CA	0.3513	40.32
TI	0.0020	0.27
FE	0.0226	2.65
TOTAL		100.00

21-SEP-87 13:36:30

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE638E RPP87-10A CL GRADIENT 3N

ELEMENT	RELATIVE K	WT %
NA	0.0603	16.84
AL	0.0320	5.99
SI	0.0749	11.89
S	0.0474	6.19
CL	0.1023	13.35
K	0.0092	1.08
CA	0.3601	41.43
TI	0.0018	0.25
FE	0.0254	2.98
TOTAL		100.00

21-SEP-87 13:37:10

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE639E RPP87-10A CL GRADIENT 3N

ELEMENT	RELATIVE K	WT %
NA	0.0637	17.59
AL	0.0292	5.51
SI	0.0708	11.18
S	0.0518	6.71
CL	0.1100	14.34
K	0.0089	1.04
CA	0.3517	40.62
TI	0.0018	0.25
FE	0.0235	2.76
TOTAL		100.00

21-SEP-87 13:37:50

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE640E RPP87-10A CL GRADIENT 3N

ELEMENT	RELATIVE K	WT %
NA	0.0685	18.48
AL	0.0313	5.90
SI	0.0750	11.93
S	0.0365	4.77
CL	0.1249	16.12
K	0.0066	0.78
CA	0.3387	39.18
TI	0.0015	0.20
FE	0.0226	2.64
TOTAL		100.00

21-SEP-87 13:38:30

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE633E RPP87-10A CL GRADIENT 3N

ELEMENT	RELATIVE K	WT %
NA	0.0650	17.89
AL	0.0288	5.43
SI	0.0705	11.15
S	0.0547	7.09
CL	0.1013	13.26
K	0.0093	1.10
CA	0.3582	41.26
TI	0.0024	0.33
FE	0.0212	2.49
TOTAL		100.00

21-SEP-87 13:33:17

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE634E RPP87-10A CL GRADIENT 3N

ELEMENT	RELATIVE K	WT %
NA	0.0592	16.66
AL	0.0311	5.84
SI	0.0808	12.81
S	0.0454	6.00
CL	0.0883	11.57
K	0.0094	1.09
CA	0.3746	42.85
TI	0.0012	0.16
FE	0.0257	3.02
TOTAL		100.00

21-SEP-87 13:33:57

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE635E RPP87-10A CL GRADIENT 3N

ELEMENT	RELATIVE K	WT %
NA	0.0658	17.00
AL	0.0312	5.64
SI	0.1067	16.45
S	0.0490	6.60
CL	0.1141	15.34
K	0.0113	1.38
CA	0.2989	35.17
TI	0.0011	0.15
FE	0.0194	2.27
TOTAL		100.00

21-SEP-87 13:34:37

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE636E RPP87-10A CL GRADIENT 3N

ELEMENT	RELATIVE K	WT %
NA	0.0641	17.69
AL	0.0301	5.67
SI	0.0839	15.33
S	0.0409	5.43
CL	0.0949	12.42
K	0.0084	0.98
CA	0.3617	41.44
TI	0.0010	0.14
FE	0.0247	2.89
TOTAL		100.00

21-SEP-87 13:35:17

Table B4

Sample 3F, 4 Weeks, Cut Near End

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE625E RPP8710A CL GRADIENT 3F

ELEMENT	RELATIVE K	WT %
NA	0.0740	19.79
AL	0.0341	6.53
SI	0.0624	10.12
S	0.0443	5.75
CL	0.1205	15.63
K	0.0055	0.65
CA	0.3347	38.67
TI	0.0009	0.12
FE	0.0233	2.73
TOTAL		100.00

21-SEP-87 12:41:10

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE626E RPP87-10A CL GRADIENT 3F

ELEMENT	RELATIVE K	WT %
NA	0.0528	15.25
AL	0.0381	7.10
SI	0.0723	11.63
S	0.0429	5.63
CL	0.0922	11.98
K	0.0076	0.88
CA	0.3826	43.62
TI	0.0027	0.38
FE	0.0301	3.54
TOTAL		100.00

21-SEP-87 12:41:16

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE627E RPP87-10A CL GRADIENT 3F

ELEMENT	RELATIVE K	WT %
NA	0.0832	21.69
AL	0.0317	6.15
SI	0.0568	9.24
S	0.0415	5.34
CL	0.1366	17.58
K	0.0053	0.63
CA	0.3174	36.85
TI	0.0007	0.09
FE	0.0208	2.43
TOTAL		100.00

21-SEP-87 12:42:21

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE628E RPP87-10A CL GRADIENT 3F

ELEMENT	RELATIVE K	WT %
NA	0.0759	20.39
AL	0.0292	5.65
SI	0.0576	9.28
S	0.0475	6.10
CL	0.1228	15.85
K	0.0047	0.56
CA	0.3417	39.42
TI	0.0014	0.19
FE	0.0218	2.55
TOTAL		100.00

21-SEP-87 12:43:17

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE645E RPP87-10A CL GRADIENT 3F

ELEMENT	RELATIVE K	WT %
NA	0.0900	23.42
AL	0.0251	4.99
SI	0.0534	8.67
S	0.0407	5.21
CL	0.1415	18.11
K	0.0037	0.44
CA	0.3146	36.48
TI	0.0000	0.00
FE	0.0230	2.67
TOTAL		100.00

21-SEP-87 12:41:36

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE646E RPP87-10A CL GRADIENT 3F

ELEMENT	RELATIVE K	WT %
NA	0.0843	22.21
AL	0.0274	5.39
SI	0.0524	8.49
S	0.0418	5.33
CL	0.1408	17.89
K	0.0044	0.53
CA	0.3238	37.52
TI	0.0004	0.05
FE	0.0222	2.59
TOTAL		100.00

21-SEP-87 12:42:17

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE647E RPP87-10A CL GRADIENT 3F

ELEMENT	RELATIVE K	WT %
NA	0.0909	23.69
AL	0.0226	4.51
SI	0.0567	9.17
S	0.0362	4.64
CL	0.1454	18.54
K	0.0037	0.44
CA	0.3121	36.20
TI	0.0000	0.00
FE	0.0241	2.80
TOTAL		100.00

21-SEP-87 12:43:42

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE648E RPP87-10A CL GRADIENT 3F

ELEMENT	RELATIVE K	WT %
NA	0.0718	19.47
AL	0.0300	5.75
SI	0.0647	10.38
S	0.0411	5.31
CL	0.1226	15.78
K	0.0052	0.61
CA	0.3459	39.87
TI	0.0008	0.10
FE	0.0232	2.71
TOTAL		100.00

21-SEP-87 12:44:21

Table B4 (Concluded)

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE629E RPP87-10A CL GRADIENT 3F

ELEMENT	RELATIVE K	WT %
NA	0.0942	23.69
AL	0.0290	5.70
SI	0.0584	9.51
S	0.0401	5.18
CL	0.1463	18.87
K	0.0029	0.35
CA	0.2954	34.46
TI	0.0004	0.05
FE	0.0189	2.20
TOTAL		100.00

21-SEP-87 12:44:36

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE630E RPP87-10A CL GRADIENT 3F

ELEMENT	RELATIVE K	WT %
NA	0.0980	24.78
AL	0.0282	5.63
SI	0.0516	8.50
S	0.0356	4.57
CL	0.1482	18.94
K	0.0040	0.49
CA	0.2978	34.64
TI	0.0000	0.00
FE	0.0211	2.45
TOTAL		100.00

21-SEP-87 12:45:16

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE631E RPP87-10A CL GRADIENT 3F

ELEMENT	RELATIVE K	WT %
NA	0.0664	18.45
AL	0.0305	5.84
SI	0.0670	10.76
S	0.0375	4.87
CL	0.1128	14.48
K	0.0075	0.87
CA	0.3621	41.52
TI	0.0018	0.25
FE	0.0252	2.96
TOTAL		100.00

21-SEP-87 12:45:55

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE632E RPP87-10A CL GRADIENT 3F

ELEMENT	RELATIVE K	WT %
NA	0.0707	19.18
AL	0.0313	5.99
SI	0.0622	9.98
S	0.0518	6.69
CL	0.1143	14.88
K	0.0029	0.34
CA	0.3485	40.14
TI	0.0008	0.11
FE	0.0229	2.68
TOTAL		100.00

21-SEP-87 12:46:35

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE641E RPP87-10A CL GRADIENT 3F

ELEMENT	RELATIVE K	WT %
NA	0.0798	21.56
AL	0.0284	5.59
SI	0.0537	8.75
S	0.0403	5.17
CL	0.1273	16.28
K	0.0032	0.37
CA	0.3400	39.10
TI	0.0010	0.14
FE	0.0259	3.02
TOTAL		100.00

21-SEP-87 12:47:48

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE642E RPP87-10A CL GRADIENT 3F

ELEMENT	RELATIVE K	WT %
NA	0.0865	22.68
AL	0.0284	5.61
SI	0.0550	8.98
S	0.0373	4.80
CL	0.1352	17.29
K	0.0031	0.37
CA	0.3249	37.52
TI	0.0014	0.19
FE	0.0221	2.57
TOTAL		100.00

21-SEP-87 12:48:28

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE643E RPP87-10A CL GRADIENT 3F

ELEMENT	RELATIVE K	WT %
NA	0.0828	22.10
AL	0.0283	5.57
SI	0.0539	8.80
S	0.0407	5.22
CL	0.1316	16.86
K	0.0037	0.44
CA	0.3285	37.91
TI	0.0006	0.08
FE	0.0259	3.02
TOTAL		100.00

21-SEP-87 12:49:08

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DE644E RPP87-10A CL GRADIENT 3F

ELEMENT	RELATIVE K	WT %
NA	0.0666	18.53
AL	0.0305	5.84
SI	0.0609	9.79
S	0.0467	6.82
CL	0.1094	14.11
K	0.0041	0.46
CA	0.3691	42.25
TI	0.0005	0.07
FE	0.0248	2.91
TOTAL		100.00

21-SEP-87 12:49:48

Table B5

Sample 1N, 11 Weeks, Cut Near Interface

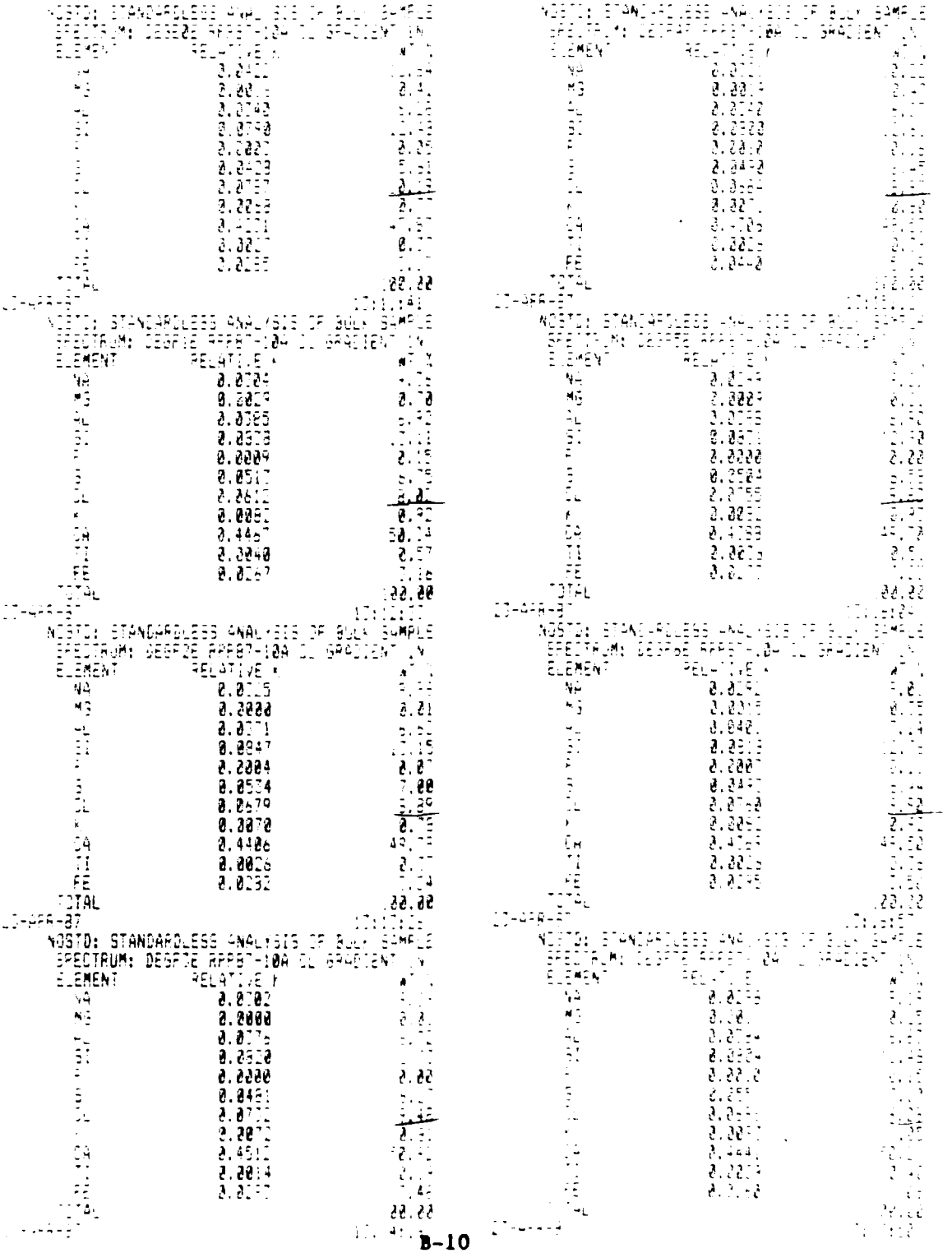


Table B5 (Concluded)

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DEG?BE RPP87-10A CL GRADIENT IN

ELEMENT	RELATIVE K	WT %
NA	0.0268	8.34
MG	0.0023	0.54
AL	0.0378	6.72
SI	0.0907	14.05
P	0.0006	0.2[illegible]
S	0.0515	6.31
CL	0.0576	7.84
K	0.0081	0.90
CA	0.4501	50.74
TI	0.0034	0.46
FE	0.0294	3.43
TOTAL		100.00

[illegible]-APR-87 13:20:[illegible]

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DEG??E RPP87-10A CL GRADIENT IN

ELEMENT	RELATIVE K	WT %
NA	0.0265	8.30
MG	0.0022	0.53
AL	0.0378	6.73
SI	0.0877	13.61
P	0.0005	0.08
S	0.0552	7.28
CL	0.0577	7.59
K	0.0094	1.05
CA	0.4491	50.55
TI	0.0036	0.51
FE	0.0308	3.65
TOTAL		100.00

[illegible]-APR-87 13:21:1[illegible]

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DEG?0E RPP87-10A CL GRADIENT IN

ELEMENT	RELATIVE K	WT %
NA	0.0294	9.14
MG	0.0004	0.11
AL	0.0369	6.58
SI	0.0873	13.53
P	0.0005	0.08
S	0.0528	6.94
CL	0.0602	7.89
K	0.0080	0.90
CA	0.4527	51.00
TI	0.0023	0.37
FE	0.0290	3.44
TOTAL		100.00

[illegible]-APR-87 13:22:06

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DEG61E RPP87-10A CL GRADIENT IN

ELEMENT	RELATIVE K	WT %
NA	0.0440	12.98
MG	0.0000	0.01
AL	0.0315	5.75
SI	0.0771	11.98
P	0.0007	0.11
S	0.0497	5.44
CL	0.0379	[illegible]
K	0.0081	0.94
CA	0.4161	47.7[illegible]
TI	0.0017	0.[illegible]
FE	0.02[illegible]	[illegible]
TOTAL		[illegible]00.00

[illegible]

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: [illegible] RPP87-10A CL GRADIENT IN

ELEMENT	RELATIVE K	WT %
NA	0.02[illegible]	[illegible]
MG	0.00[illegible]	0.5[illegible]
AL	0.0405	[illegible]
SI	0.08[illegible]	[illegible]
P	0.00[illegible]	[illegible]
S	0.0497	[illegible]
CL	0.07[illegible]	[illegible]
K	0.0064	0.[illegible]
CA	0.4278	48.[illegible]
TI	0.00[illegible]	0.4[illegible]
FE	0.0257	[illegible].04
TOTAL		100.00

[illegible]-APR-87 13:[illegible]

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DEG??E RPP87-10A CL GRADIENT IN

ELEMENT	RELATIVE K	WT %
NA	0.0287	[illegible]
MG	0.0003	0.[illegible]
AL	0.03[illegible]	6.[illegible]
SI	0.0890	[illegible]
P	0.0010	0.[illegible]
S	0.0507	[illegible]
CL	0.0651	[illegible]
K	0.0073	0.[illegible]
CA	0.4480	[illegible]
TI	0.00[illegible]	0.[illegible]
FE	0.0150	[illegible]
TOTAL		100.00

[illegible]

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DEG??E RPP87-10A CL GRADIENT IN

ELEMENT	RELATIVE K	WT %
NA	0.0[illegible]	12.[illegible]
MG	0.0006	0.[illegible]
AL	0.0[illegible]	[illegible]
SI	0.0[illegible]	[illegible]
P	0.0001	0.[illegible]
S	0.04[illegible]	[illegible]
CL	0.0[illegible]	[illegible]
K	0.0[illegible]	[illegible]
CA	0.4[illegible]	[illegible]
TI	0.0025	[illegible]
FE	0.0[illegible]	[illegible]
TOTAL		[illegible]

[illegible]-APR-87 [illegible]

NOSTD: STANDARDLESS ANALYSIS OF BULK SAMPLE
SPECTRUM: DEG??E RPP87-10A CL GRADIENT IN

ELEMENT	RELATIVE K	WT %
NA	[illegible]	[illegible]
MG	0.0000	0.[illegible]
AL	[illegible]	[illegible]
SI	[illegible]	[illegible]
P	[illegible]	[illegible]
S	[illegible]	[illegible]
CL	[illegible]	[illegible]
K	[illegible]	[illegible]
CA	[illegible]	[illegible]
TI	0.00[illegible]	[illegible]
FE	[illegible]	[illegible]
TOTAL		[illegible]

[illegible]

Table B6

Sample 1F, 11 Weeks, Cut Near End

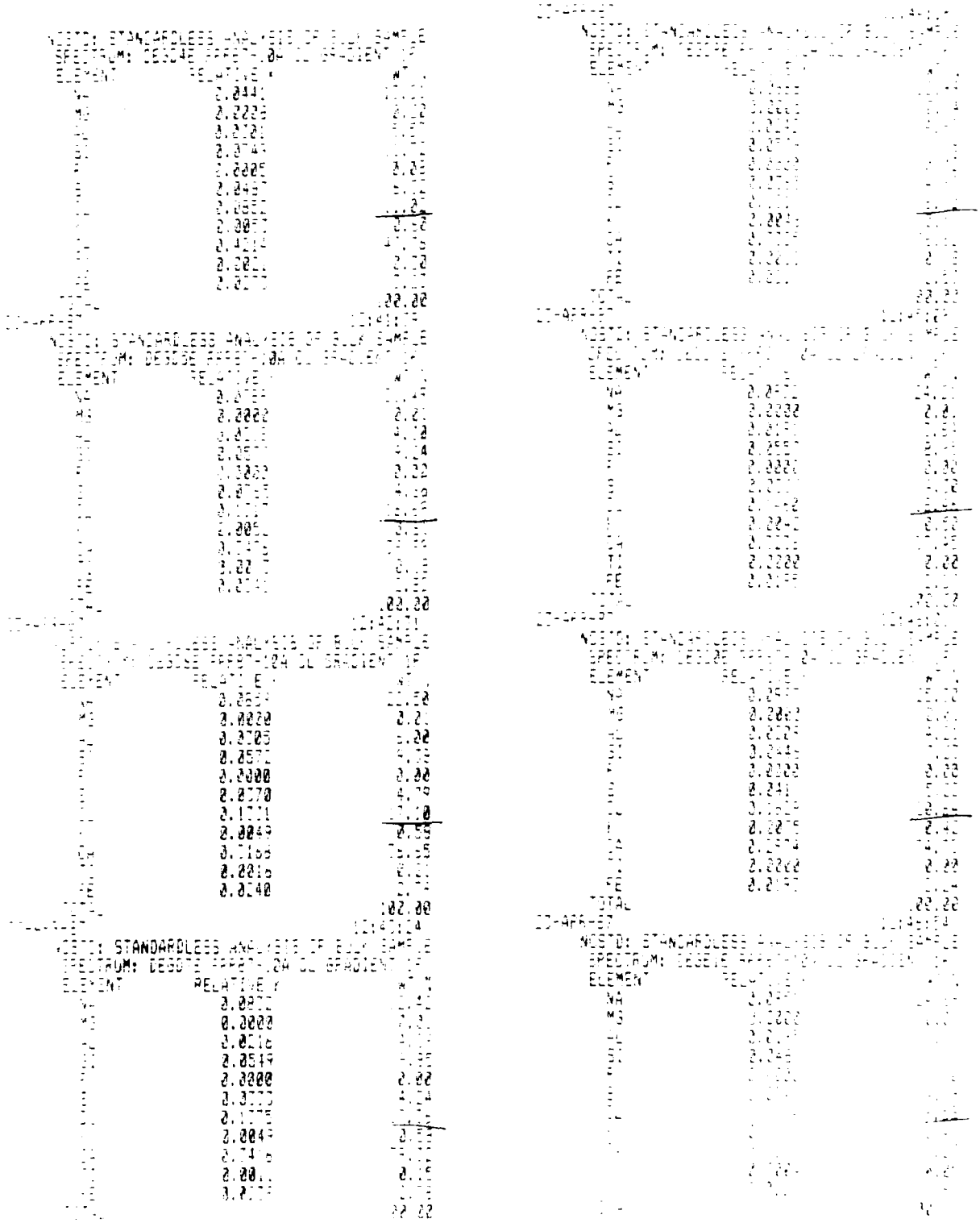


Table B6 (Concluded)

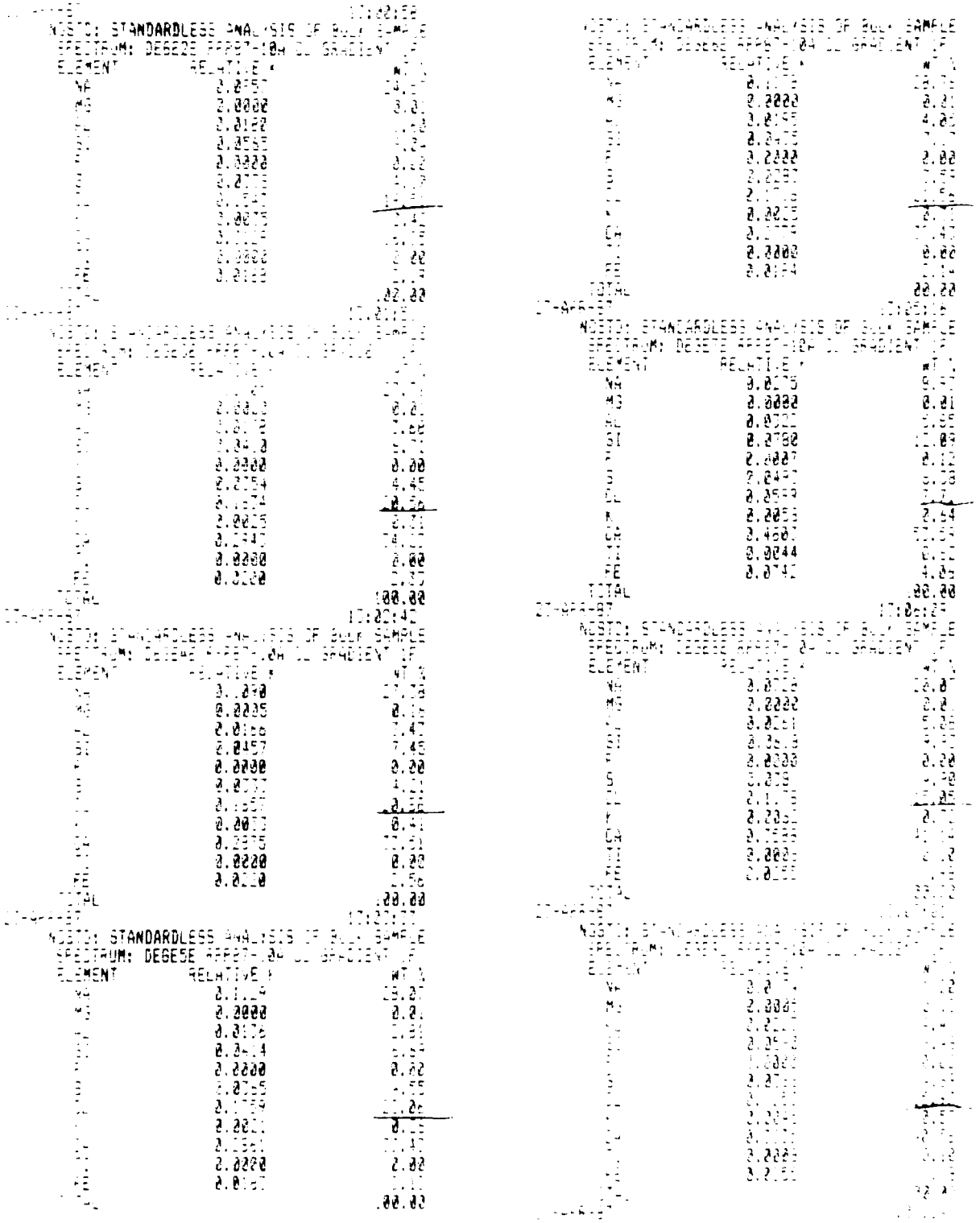


Table B7

Sample 6N, 11 Weeks, Cut Near Interface

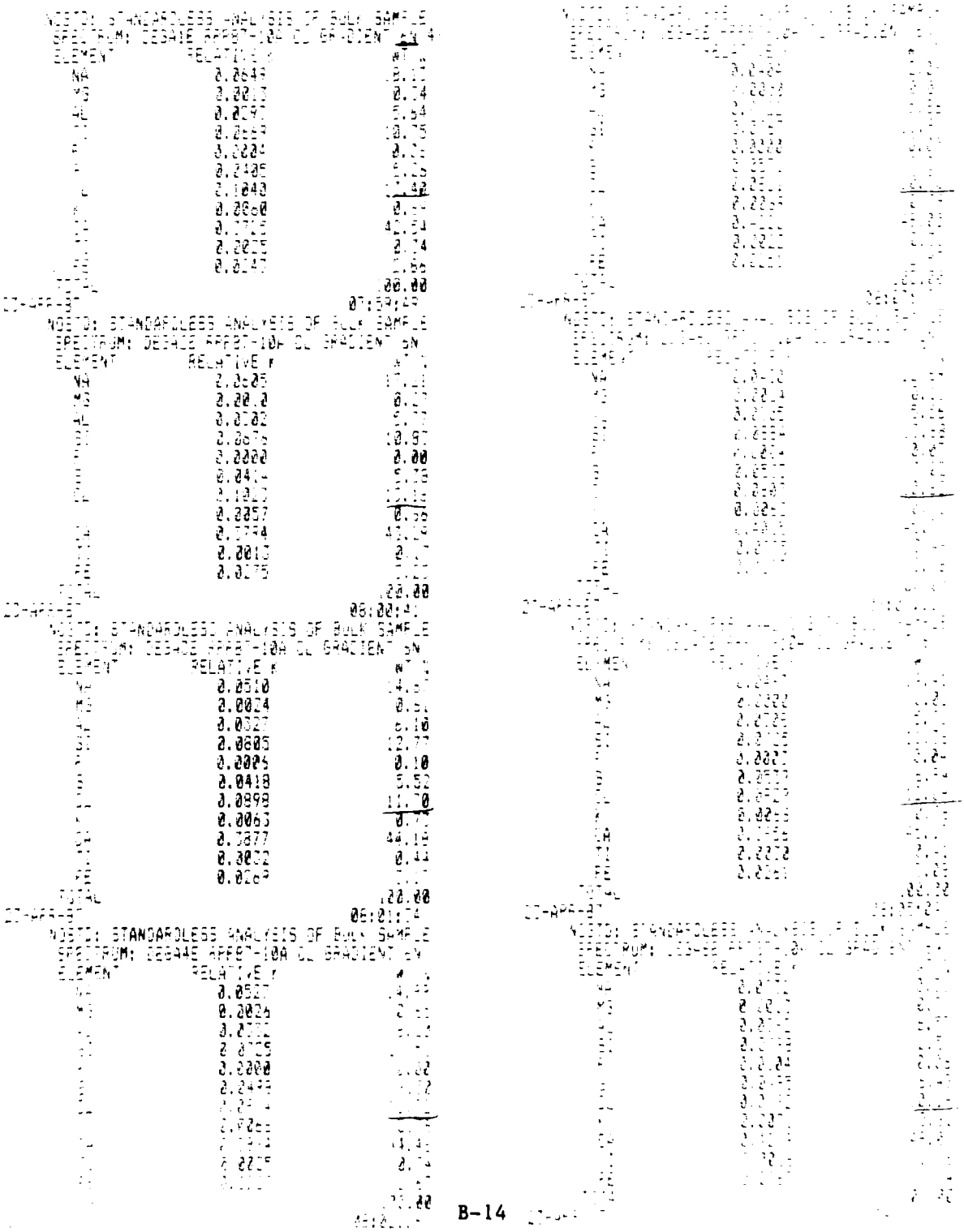


Table B7 (Concluded)

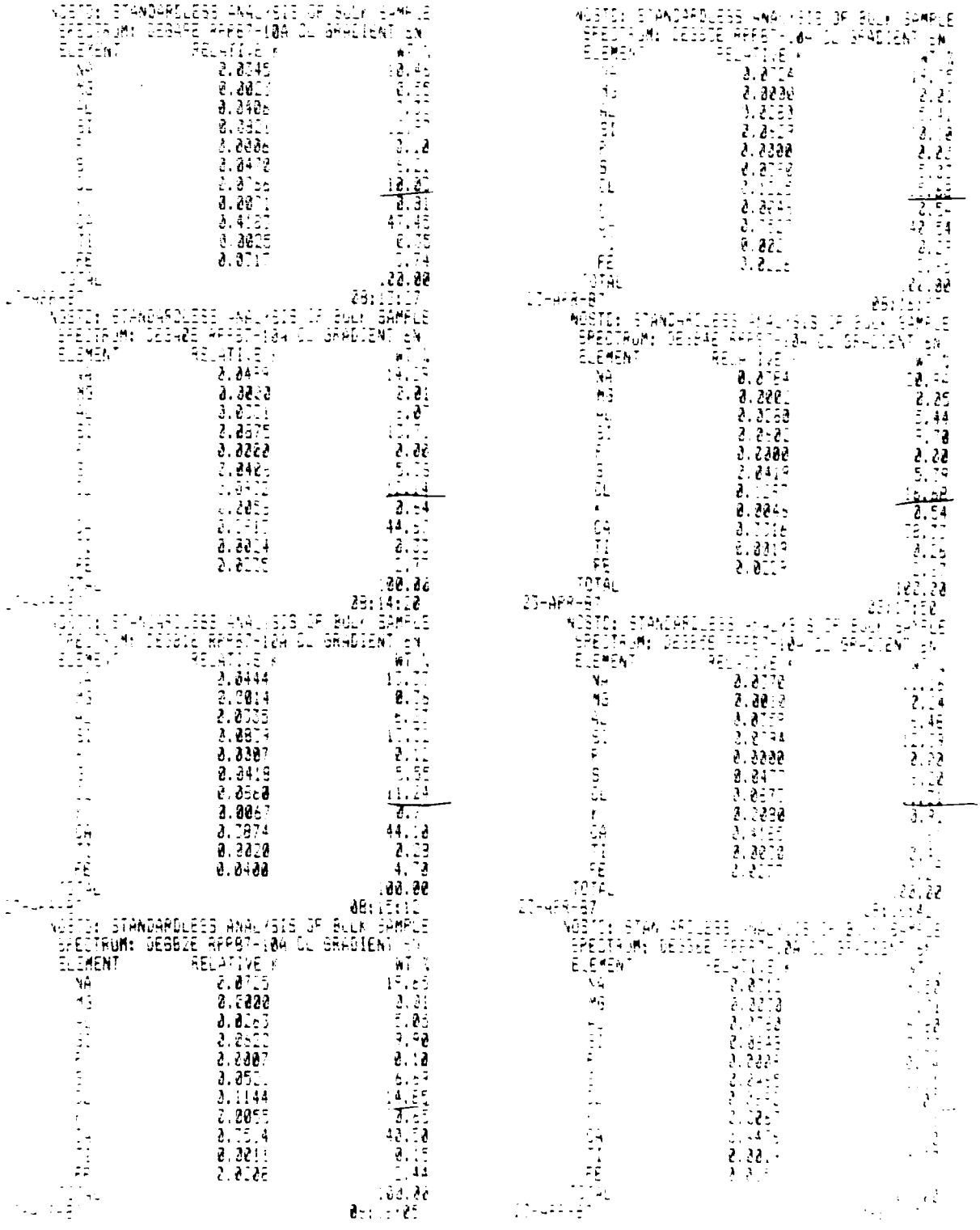


Table B8

Sample 6F, 11 Weeks, Cut Near End

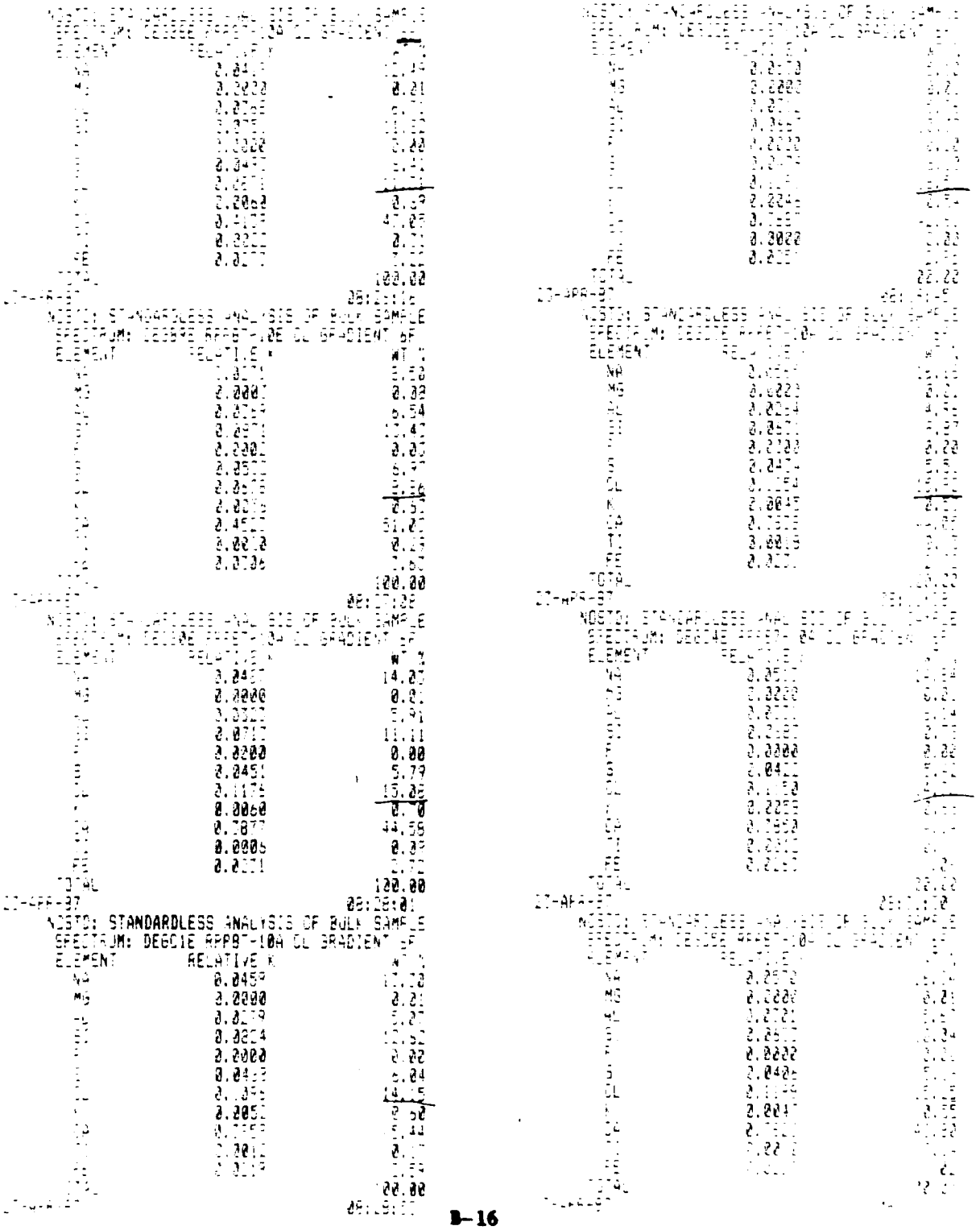
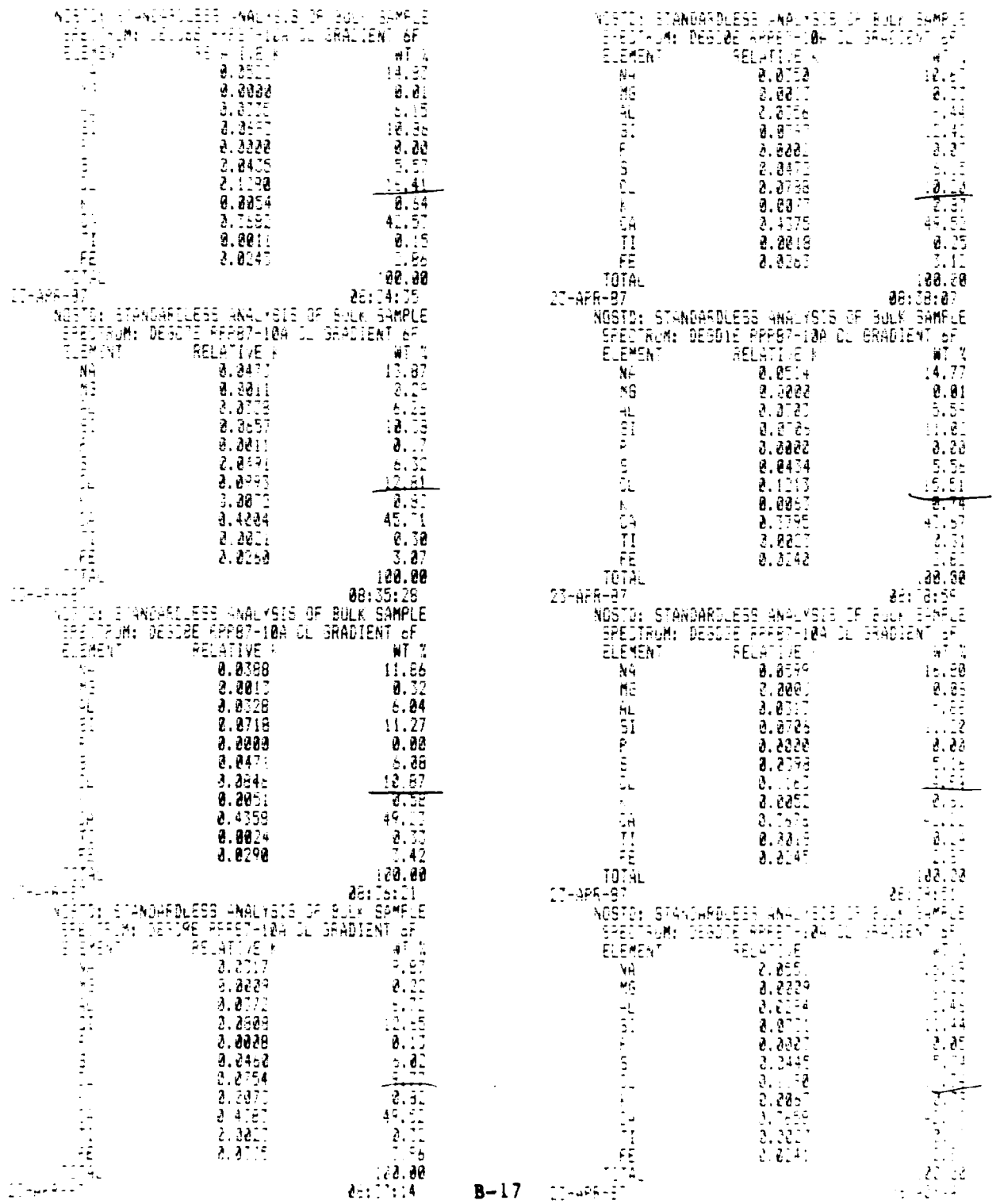


Table B8 (Concluded)



APPENDIX C

DATA AND ANALYSIS OF VARIANCE (ANOVA's) FOR THREE EXPOSURE SOLUTIONS (TASK 3)

KEY TO VARIABLE NAMES

EXP_TIME=exposure time (7, 45, 90 days)

EXP_SOLN=exposure solution (water, half-saturated brine, saturated brine)

TEMP=exposure temperature (27, 38° C)

CURE=length of cure prior to exposure (28 days, 9 months)

SUMMARY OF RESULTS

Exposure Time = 7 Days

Cure	Temp	Solution	Repl	% Change Thickness	% Change Mass	SO_4	Ca	Al	Si
28 d	27	1/2 sat	1	0.64	-6.14	39	.	.	.
28 d	27	1/2 sat	2	0.58	-3.03	136	.	.	.
28 d	27	sat	1	2.76	-2.93	78	.	.	.
28 d	27	sat	2	2.85	0.79	83	.	.	.
28 d	27	water	1	1.15	-7.96	2	.	.	.
28 d	27	water	2	1.07	-4.55	22	.	.	.
28 d	38	1/2 sat	1	0.39	-4.95	108	.	.	.
28 d	38	1/2 sat	2	0.59	-3.00	214	.	.	.
28 d	38	sat	1	3.69	-2.44	130	.	.	.
28 d	38	sat	2	2.40	-1.01	185	.	.	.
28 d	38	water	1	0.59	-7.36	7	.	.	.
28 d	38	water	2	1.34	-6.95	39	.	.	.
9 m	27	1/2 sat	1	.	-2.05	69	.	.	.
9 m	27	1/2 sat	2	.	-4.05	74	.	.	.
9 m	27	sat	1	.	-1.49	7	.	.	.
9 m	27	sat	2	.	-1.45	36	.	.	.
9 m	27	water	1	.	-2.81	3	.	.	.
9 m	27	water	2	.	-2.98	35	.	.	.
9 m	38	1/2 sat	1	.	-2.39	161	.	.	.
9 m	38	1/2 sat	2	.	-3.33	149	.	.	.
9 m	38	sat	1	.	-1.87	117	.	.	.
9 m	38	sat	2	.	-3.38	152	.	.	.
9 m	38	water	1	.	-2.31	13	.	.	.
9 m	38	water	2	.	-5.76	0	.	.	.

Exposure Time = 45 Days

28 d	27	1/2 sat	1	1.72	-2.38	99	.	.	.
28 d	27	1/2 sat	2	3.05	-0.82	120	.	.	.
28 d	27	sat	1	3.14	-1.60	132	.	.	.
28 d	27	sat	2	2.95	-0.13	139	.	.	.
28 d	27	water	1	9.10	-4.71	50	.	.	.
28 d	27	water	2	5.00	-2.68	12	.	.	.
28 d	38	1/2 sat	1	3.30	-3.38	203	.	.	.
28 d	38	1/2 sat	2	3.13	-1.71	216	.	.	.
28 d	38	sat	1	5.80	-1.11	201	.	.	.
28 d	38	sat	2	2.89	-0.42	212	.	.	.
28 d	38	water	1	4.19	-5.72	63	.	.	.
28 d	38	water	2	2.25	-6.84	66	.	.	.
9 m	27	1/2 sat	1	2.74	-3.15	112	.	.	.
9 m	27	1/2 sat	2	1.25	-4.04	132	.	.	.
9 m	27	sat	1	3.23	-2.82	120	.	.	.
9 m	27	sat	2	4.12	-2.95	149	.	.	.
9 m	27	water	1	2.35	-2.30	35	.	.	.
9 m	27	water	2	2.65	-2.50	28	.	.	.
9 m	38	1/2 sat	1	4.71	-7.55	295	.	.	.
9 m	38	1/2 sat	2	4.30	-4.60	177	.	.	.
9 m	38	sat	1	0.31	-3.06	219	.	.	.
9 m	38	sat	2	2.90	-4.36	256	.	.	.
9 m	38	water	1	5.43	-7.95	90	.	.	.
9 m	38	water	2	5.73	-5.89	53	.	.	.

SUMMARY OF RESULTS continued

Exposure Time - 90 Days

Cure	Temp	Solution	Repl	% Change Thickness	% Change Mass	SO_4	Ca	Al	Si
28 d	27	1/2 sat	1	-1.2	-4.13	146	747	6	3
28 d	27	1/2 sat	2	2.48	-1.97	151	394	7	3
28 d	27	sat	1	0.53	-2.84	170	791	7	1
28 d	27	sat	2	1.31	-1.87	204	1002	12	1
28 d	27	water	1	10.6	-5.69	94	985	5	8
28 d	27	water	2	0.49	-3.08	43	456	6	9
28 d	38	1/2 sat	1	0.83	-3.14	229	538	9	3
28 d	38	1/2 sat	2	8.82	-2.84	195	839	7	3
28 d	38	sat	1	1.44	-3.62	207	630	7	2
28 d	38	sat	2	0.22	-0.65	211	649	5	4
28 d	38	water	1	2.39	-2.14	58	673	9	9
28 d	38	water	2	1.79	-6.48	109	1356	9	14
9 m	27	1/2 sat	1	0.68	-3.17	141	1014	10	5
9 m	27	1/2 sat	2	2.10	-3.87	128	950	11	5
9 m	27	sat	1	1.89	-3.36	163	776	10	1
9 m	27	sat	2	1.57	-5.71	208	936	13	1
9 m	27	water	1	0.00	-5.60	85	1237	8	12
9 m	27	water	2	3.41	-6.96	72	1226	10	13
9 m	38	1/2 sat	1	0.94	-6.42	323	1303	10	3
9 m	38	1/2 sat	2	2.07	-10.1	262	883	24	2
9 m	38	sat	1	1.05	-4.63	332	1073	13	1
9 m	38	sat	2	3.06	-8.11	90	1086	12	3
9 m	38	water	1	4.15	-7.25	190	1747	10	15
9 m	38	water	2	4.80	-9.35	101	1142	7	13

1. Analysis of Variance for Dependent Variable = % Change in Thickness

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
EXP_TIME	3	7 45 90
EXP_SOLN	3	HS SAT WATER
TEMP	2	27 38
CURE	2	DAY28 MO9

NUMBER OF OBSERVATIONS IN DATA SET = 72

NOTE: ALL DEPENDENT VARIABLES ARE CONSISTENT WITH RESPECT TO THE PRESENCE OR ABSENCE OF MISSING VALUES. HOWEVER, ONLY 60 OBSERVATIONS CAN BE USED IN THIS ANALYSIS.

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	18	103.76430899	5.76468383
ERROR	41	186.27837759	4.54337506
CORRECTED TOTAL	59	290.04268658	

MODEL F =	PR > F =
1.27	0.2576

R-SQUARE	C.V.	ROOT MSE	PCT_THK MEAN
0.357755	80.1163	2.13151943	2.66053235

SOURCE	DF	ANOVA SS	F VALUE	PR > F
EXP_TIME	2	39.95806933	4.40	0.0186
EXP_SOLN	2	17.99250444	1.98	0.1510
TEMP	1	2.16207992	0.48	0.4942
CURE	1	0.17631992	0.04	0.8448
EXP_TIME*EXP_SOLN	4	24.11412565	1.33	0.2762
EXP_TIME*TEMP	2	0.91079793	0.10	0.9048
EXP_TIME*CURE	1	2.37863067	0.52	0.4734
EXP_SOLN*TEMP	2	9.71442113	1.07	0.3527
EXP_SOLN*CURE	2	0.85993914	0.09	0.9099
TEMP*CURE	1	5.49742086	1.21	0.2778

1.a. Duncan's Multiple Range Test Comparisons Among Exposure Times

NOTE: THIS TEST CONTROLS THE TYPE I COMPARISONWISE ERROR RATE,
NOT THE EXPERIMENTWISE ERROR RATE

ALPHA=0.05 DF=41 MSE=4.54338

WARNING: CELL SIZES ARE NOT EQUAL.
HARMONIC MEAN OF CELL SIZES=18

NUMBER OF MEANS	2	3
CRITICAL RANGE	1.43498	1.50859

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

DUNCAN GROUPING	MEAN	N	EXP_TIME
A	3.5935	24	45
A			
B A	2.3058	24	90
B			
B	1.5041	12	7

1.b. Duncan's Multiple Range Test comparisons Among Exposure Solutions

NOTE: THIS TEST CONTROLS THE TYPE I COMPARISONWISE ERROR RATE,
NOT THE EXPERIMENTWISE ERROR RATE

ALPHA=0.05 DF=41 MSE=4.54338

NUMBER OF MEANS	2	3
CRITICAL RANGE	1.36134	1.43117

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

DUNCAN GROUPING	MEAN	N	EXP_SOLN
A	3.4212	20	WATER
A			
A	2.4061	20	SAT
A			
A	2.1543	20	HS

1.c. Duncan's Multiple Range Test Comparisons Among Exposure Temperatures

NOTE: THIS TEST CONTROLS THE TYPE I COMPARISONWISE ERROR RATE,
NOT THE EXPERIMENTWISE ERROR RATE

ALPHA=0.05 DF=41 MSE=4.54338

NUMBER OF MEANS 2
CRITICAL RANGE 1.11153

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

DUNCAN GROUPING	MEAN	N	TEMP
A	2.8504	30	38
A			
A	2.4707	30	27

1.d. Duncan's Multiple Range Test Comparisons Among Length of Cure Prior to Exposure

NOTE: THIS TEST CONTROLS THE TYPE I COMPARISONWISE ERROR RATE,
NOT THE EXPERIMENTWISE ERROR RATE

ALPHA=0.05 DF=41 MSE=4.54338

WARNING: CELL SIZES ARE NOT EQUAL.
HARMONIC MEAN OF CELL SIZES=28.8

NUMBER OF MEANS 2
CRITICAL RANGE 1.13445

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

DUNCAN GROUPING	MEAN	N	CURE
A	2.7269	24	MO9
A			
A	2.6163	36	DAY28

2. **Analysis of Variance for Dependent Variable = Change in Mass**

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
EXP_TIME	3	7 45 90
EXP_SOLN	3	HS SAT WATER
TEMP	2	27 38
CURE	2	DAY28 MO9

NUMBER OF OBSERVATIONS IN DATA SET = 72

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: PCT_MASS

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	19	265.06529641	13.95080507
ERROR	52	112.88151320	2.17079833
CORRECTED TOTAL	71	377.94680961	

MODEL F =	6.43	PR > F =	0.0001

R-SQUARE	C.V.	ROOT MSE	PCT_MASS MEAN
0.701330	38.0158	1.47336293	3.87565461

SOURCE	DF	ANOVA SS	F VALUE	PR > F
EXP_TIME	2	24.97351402	5.75	0.0055
EXP_SOLN	2	87.54643461	20.16	0.0001
TEMP	1	28.30433622	13.04	0.0007
CURE	1	22.34876067	10.30	0.0023
EXP_TIME*EXP_SOLN	4	4.85264612	0.56	0.6935
EXP_TIME*TEMP	2	5.74564338	1.32	0.2750
EXP_TIME*CURE	2	58.39452359	13.45	0.0001
EXP_SOLN*TEMP	2	4.03421678	0.93	0.4013
EXP_SOLN*CURE	2	17.14288099	3.95	0.0253
TEMP*CURE	1	11.72234003	5.40	0.0241

2.a. Duncan's Multiple Range Test Comparisons Among Exposure Times

NOTE: THIS TEST CONTROLS THE TYPE I COMPARISONWISE ERROR RATE,
NOT THE EXPERIMENTWISE ERROR RATE

ALPHA=0.05 DF=52 MSE=2.1708

NUMBER OF MEANS	2	3
CRITICAL RANGE	0.853865	0.897774

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

DUNCAN GROUPING	MEAN	N	EXP_TIME
A	4.7084	24	90
B	3.4746	24	7
B			
B	3.4440	24	45

2.b. Duncan's Multiple Range Test Comparisons Among Exposure Solutions

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE: PCT_MASS
NOTE: THIS TEST CONTROLS THE TYPE I COMPARISONWISE ERROR RATE,
NOT THE EXPERIMENTWISE ERROR RATE

ALPHA=0.05 DF=52 MSE=2.1708

NUMBER OF MEANS	2	3
CRITICAL RANGE	0.853865	0.897774

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

DUNCAN GROUPING	MEAN	N	EXP_SOLN
A	5.2422	24	WATER
B	3.8429	24	HS
C	2.5418	24	SAT

2.c. Duncan's Multiple Range Test Comparisons Among Exposure Temperatures

NOTE: THIS TEST CONTROLS THE TYPE I COMPARISONWISE ERROR RATE,
NOT THE EXPERIMENTWISE ERROR RATE

ALPHA=0.05 DF=52 MSE=2.1708

NUMBER OF MEANS 2
CRITICAL RANGE 0.697178

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

DUNCAN GROUPING	MEAN	N	TEMP
A	4.5026	36	38
B	3.2487	36	27

2.d. Duncan's Multiple Range Test Comparisons Among Levels of Cure

NOTE: THIS TEST CONTROLS THE TYPE I COMPARISONWISE ERROR RATE,
NOT THE EXPERIMENTWISE ERROR RATE

ALPHA=0.05 DF=52 MSE=2.1708

NUMBER OF MEANS 2
CRITICAL RANGE 0.697178

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

DUNCAN GROUPING	MEAN	N	CURE
A	4.4328	36	MO9
B	3.3185	36	DAY28

3. Analysis of Variance for Dependent Variable = Sulfate Leached

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
EXP_TIME	3	7 45 90
EXP_SOLN	3	HS SAT WATER
TEMP	2	27 38
CURE	2	DAY28 MO9

NUMBER OF OBSERVATIONS IN DATA SET = 72

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: SO4

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	19	381761.60581123	20092.71609533
ERROR	52	78406.71272510	1507.82139856
CORRECTED TOTAL	71	460168.31853633	

MODEL F =	13.33	PR > F = 0.0001

R-SQUARE	C.V.	ROOT MSE	SO4 MEAN
0.829613	31.2396	38.83067600	124.29945425

SOURCE	DF	ANOVA SS	F VALUE	PR > F
EXP_TIME	2	90057.72521833	29.86	0.0001
EXP_SOLN	2	184308.42740056	61.12	0.0001
TEMP	1	74173.51170280	49.19	0.0001
CURE	1	567.90872689	0.38	0.5421
EXP_TIME*EXP_SOLN	4	4450.33334963	0.74	0.5704
EXP_TIME*TEMP	2	1459.41118738	0.48	0.6191
EXP_TIME*CURE	2	5785.33953197	1.92	0.1571
EXP_SOLN*TEMP	2	16267.07413701	5.39	0.0074
EXP_SOLN*CURE	2	1868.89775739	0.62	0.5420
TEMP*CURE	1	2822.97679927	1.87	0.1771

3.a. Duncan's Multiple Range Test Comparisons Among Exposure Time

NOTE: THIS TEST CONTROLS THE TYPE I COMPARISONWISE ERROR RATE,
NOT THE EXPERIMENTWISE ERROR RATE

ALPHA=0.05 DF=52 MSE=1507.82

NUMBER OF MEANS	2	3
CRITICAL RANGE	22.5037	23.661

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

DUNCAN GROUPING	MEAN	N	EXP_TIME
A	162.99	24	90
B	132.40	24	45
C	77.51	24	7

3.b. Duncan's Multiple Range Test Comparisons Among Exposure Solutions

NOTE: THIS TEST CONTROLS THE TYPE I COMPARISONWISE ERROR RATE,
NOT THE EXPERIMENTWISE ERROR RATE

ALPHA=0.05 DF=52 MSE=1507.82

NUMBER OF MEANS	2	3
CRITICAL RANGE	22.5037	23.661

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

DUNCAN GROUPING	MEAN	N	EXP_SOLN
A	161.78	24	HS
A			
A	158.34	24	SAT
B	52.78	24	WATER

3.c. Duncan's Multiple Range Test Comparisons Among Exposure Temperatures

NOTE: THIS TEST CONTROLS THE TYPE I COMPARISONWISE ERROR RATE,
NOT THE EXPERIMENTWISE ERROR RATE

ALPHA=0.05 DF=52 MSE=1507.82

NUMBER OF MEANS 2
CRITICAL RANGE 18.3742

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

DUNCAN GROUPING	MEAN	N	TEMP
A	156.396	36	38
B	92.203	36	27

3.d. Duncan's Multiple Range Test Comparisons Among Length of Cures

NOTE: THIS TEST CONTROLS THE TYPE I COMPARISONWISE ERROR RATE,
NOT THE EXPERIMENTWISE ERROR RATE

ALPHA=0.05 DF=52 MSE=1507.82

NUMBER OF MEANS 2
CRITICAL RANGE 18.3742

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

DUNCAN GROUPING	MEAN	N	CURE
A	127.108	36	MO9
A			
A	121.491	36	DAY28

4. **Analysis of Variance for Dependent Variable = Calcium Leached**

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
EXP_SOLN	3	HS SAT WATER
CURE	2	DAY28 MO9
TEMP	2	27 38

NUMBER OF OBSERVATIONS IN DATA SET = 24

DEPENDENT VARIABLE: CA

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	9	1379670.59305207	153296.73256134
ERROR	14	883390.24234186	63099.30302442
CORRECTED TOTAL	23	2263060.83539393	

MODEL F =	2.43	PR > F = 0.0662

R-SQUARE	C.V.	ROOT MSE	CA MEAN
0.609648	26.8738	251.19574643	934.72251728

SOURCE	DF	ANOVA SS	F VALUE	PR > F
EXP_SOLN	2	343553.23238116	2.72	0.1003
CURE	1	775001.30215001	12.28	0.0035
TEMP	1	82131.16848348	1.30	0.2731
EXP_SOLN*CURE	2	80416.38235090	0.64	0.5434
EXP_SOLN*TEMP	2	72954.92647308	0.58	0.5738
CURE*TEMP	1	25613.58121343	0.41	0.5343

4.a. Duncan's Multiple Range Test Comparisons Among Exposure Solutions

NOTE: THIS TEST CONTROLS THE TYPE I COMPARISONWISE ERROR RATE,
NOT THE EXPERIMENTWISE ERROR RATE

ALPHA=0.05 DF=14 MSE=63099.3

NUMBER OF MEANS	2	3
CRITICAL RANGE	268.884	281.956

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

DUNCAN GROUPING	MEAN	N	EXP_SOLN
A	1102.8	8	WATER
A			
A	867.8	8	SAT
A			
A	833.6	8	HS

4.b. Duncan's Multiple Range Test Comparisons Among Length of Cure

NOTE: THIS TEST CONTROLS THE TYPE I COMPARISONWISE ERROR RATE,
NOT THE EXPERIMENTWISE ERROR RATE

ALPHA=0.05 DF=14 MSE=63099.3

NUMBER OF MEANS	2
CRITICAL RANGE	219.543

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

DUNCAN GROUPING	MEAN	N	CURE
A	1114.4	12	MO9
B	755.0	12	DAY28

4.c. Duncan's Multiple Range Test Comparisons Among Curing Temperatures

NOTE: THIS TEST CONTROLS THE TYPE I COMPARISONWISE ERROR RATE,
NOT THE EXPERIMENTWISE ERROR RATE

ALPHA=0.05 DF=14 MSE=63099.3

NUMBER OF MEANS	2
CRITICAL RANGE	219.543

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

DUNCAN GROUPING	MEAN	N	TEMP
A	993.2	12	38
A			
A	876.2	12	27

5. Analysis of Variance for Dependent Variable = Silicon Leached

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
EXP_SOLN	3	HS SAT WATER
CURE	2	DAY28 MO9
TEMP	2	27 38

NUMBER OF OBSERVATIONS IN DATA SET = 24

DEPENDENT VARIABLE: SI

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	9	519.46578779	57.71842087
ERROR	14	24.33097543	1.73792682
CORRECTED TOTAL	23	543.79676322	

MODEL F =	33.21		PR > F = 0.0001

R-SQUARE	C.V.	ROOT MSE	SI MEAN
0.955257	23.7343	1.31830452	5.55442518

SOURCE	DF	ANOVA SS	F VALUE	PR > F
EXP_SOLN	2	478.59310749	137.69	0.0001
CURE	1	6.59609375	3.80	0.0717
TEMP	1	2.86142930	1.65	0.2203
EXP_SOLN*CURE	2	14.24751173	4.10	0.0397
EXP_SOLN*TEMP	2	12.52994292	3.60	0.0546
CURE*TEMP	1	4.63770261	2.67	0.1246

5.a. Duncan's Multiple Range Test Comparisons Among Exposure Solutions

NOTE: THIS TEST CONTROLS THE TYPE I COMPARISONWISE ERROR RATE,
NOT THE EXPERIMENTWISE ERROR RATE

ALPHA=0.05 DF=14 MSE=1.73793

NUMBER OF MEANS	2	3
CRITICAL RANGE	1.41114	1.47974

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

DUNCAN GROUPING	MEAN	N	EXP_SOLN
A	11.7560	8	WATER
B	3.4866	8	HS
C	1.4206	8	SAT

5.b. Duncan's Multiple Range Test Comparison Among Lengths of Cure

NOTE: THIS TEST CONTROLS THE TYPE I COMPARISONWISE ERROR RATE,
NOT THE EXPERIMENTWISE ERROR RATE

ALPHA=0.05 DF=14 MSE=1.73793

NUMBER OF MEANS	2
CRITICAL RANGE	1.15219

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

DUNCAN GROUPING	MEAN	N	CURE
A	6.0787	12	MO9
A			
A	5.0302	12	DAY28

5.c. Duncan's Multiple Range Test Comparisons Among Curing Temperatures

NOTE: THIS TEST CONTROLS THE TYPE I COMPARISONWISE ERROR RATE,
NOT THE EXPERIMENTWISE ERROR RATE

ALPHA=0.05 DF=14 MSE=1.73793

NUMBER OF MEANS	2
CRITICAL RANGE	1.15219

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

DUNCAN GROUPING	MEAN	N	TEMP
A	5.8997	12	38
A			
A	5.2091	12	27

6. Analysis of Variance for Dependent Variable = Aluminum Leached

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
EXP_SOLN	3	HS SAT WATER
CURE	2	DAY28 MO9
TEMP	2	27 38

NUMBER OF OBSERVATIONS IN DATA SET = 24

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: AL

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	9	200.33441108	22.25937901
ERROR	14	141.68631000	10.12045071
CORRECTED TOTAL	23	342.02072109	

MODEL F =	2.20	PR > F = 0.0900

R-SQUARE	C.V.	ROOT MSE	AL MEAN
0.585738	33.3611	3.18126558	9.53585601

SOURCE	DF	ANOVA SS	F VALUE	PR > F
EXP_SOLN	2	26.68139623	1.32	0.2989
CURE	1	102.86111942	10.16	0.0066
TEMP	1	11.23374291	1.11	0.3099
EXP_SOLN*CURE	2	23.78777698	1.18	0.3374
EXP_SOLN*TEMP	2	30.16417427	1.49	0.2590
CURE*TEMP	1	5.60620127	0.55	0.4690

6.a. Duncan's Multiple Range Test Comparisons Among Exposure Solutions

NOTE: THIS TEST CONTROLS THE TYPE I COMPARISONWISE ERROR RATE,
NOT THE EXPERIMENTWISE ERROR RATE

ALPHA=0.05 DF=14 MSE=10.1205

NUMBER OF MEANS	2	3
CRITICAL RANGE	3.40528	3.57082

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

DUNCAN GROUPING	MEAN	N	EXP_SOLN
A	10.666	8	HS
A			
A	9.813	8	SAT
A			
A	8.128	8	WATER

6.b. Duncan's Multiple Range Test Comparisons Among Length of Cure

NOTE: THIS TEST CONTROLS THE TYPE I COMPARISONWISE ERROR RATE,
NOT THE EXPERIMENTWISE ERROR RATE

ALPHA=0.05 DF=14 MSE=10.1205

NUMBER OF MEANS	2
CRITICAL RANGE	2.7804

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

DUNCAN GROUPING	MEAN	N	CURE
A	11.606	12	MO9
B	7.466	12	DAY28

6.c. Duncan's Multiple Range Test Comparisons Among Curing Temperatures

NOTE: THIS TEST CONTROLS THE TYPE I COMPARISONWISE ERROR RATE,
NOT THE EXPERIMENTWISE ERROR RATE

ALPHA=0.05 DF=14 MSE=10.1205

NUMBER OF MEANS	2
CRITICAL RANGE	2.7804

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

DUNCAN GROUPING	MEAN	N	TEMP
A	10.220	12	38
A			
A	8.852	12	27

END

DATE

FILMED

4-88

DTIC